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TRACE ELEMENT ANOMALIES IN THE IGNEOUS WALL ROCKS OF HYDROTHERMAL VEINS IN THE SEARCHLIGHT DISTRICT, NEVADA

BY 440

ZUHAIR AL-SHAIEB, 1940

A

THESIS

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ABSTRACT

Two hundred and fifty vein and wall rock samples were collected from Chief of the Hill and the Duplex Mines of Searchlight District, Nevada. The samples were collected along lines approximately normal to the veins. They were analyzed for lead, copper, zinc, silver, gold, arsenic, selenium, and molybdenum using neutron actication analysis and atomic absorption spectrophotometry.

Gold, silver, copper, lead and zinc show well-developed anomalies in the wall rocks. In most cases, the concentration of these elements decreases gradually with increasing distance from the vein and reaches background values at a distance of 40-120 feet from the vein.

Molybdenum and selenium did not show a significant difference in concentration between vein material and wall rock. The arsenic concentration was below the detection limit of the used analytical method.

The available results indicate that the concentration of metal in the vein strongly influences the extent of the wall rock anomaly. The results also indicate that anomalies are better developed in the hanging wall than in the footwall of a vein.

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I. INTRODUCTION

A. Purpose of Study

The purpose of this study is fivefold:

1. To study the shape and extent of the gold, silver, lead, copper, zinc, selenium, arsenic and molybdenum anomalies in the igneous wall rocks of the epithermal type veins in the Searchlight District, Nevada.

2. To present a comprehensive discussion concerning the penetration of these trace elements in the wall rock. Also, to discuss the main factors which influence this penetration in order to establish some geochemical evidence for making this problem more understandable.

3. To study the mode (or trend) of the dispersion patterns of the different trace elements in the igneous wall rock. Also, to prove that the dispersion is a function of many variables.

4. To determine the distribution relationships among the trace elements through statistical techniques and to study and evaluate the decrease in the relation between trace element concentration prependicular to the vein.

5. To provide more scientific data for the exploration methods for these elements.

B. Location of the Area

The Searchlight Mining District is located in southeastern Clark County, Nevada, 12 miles west of the Colorado River, 40 miles south of Boulder City and 22 miles east of Nipton, California.

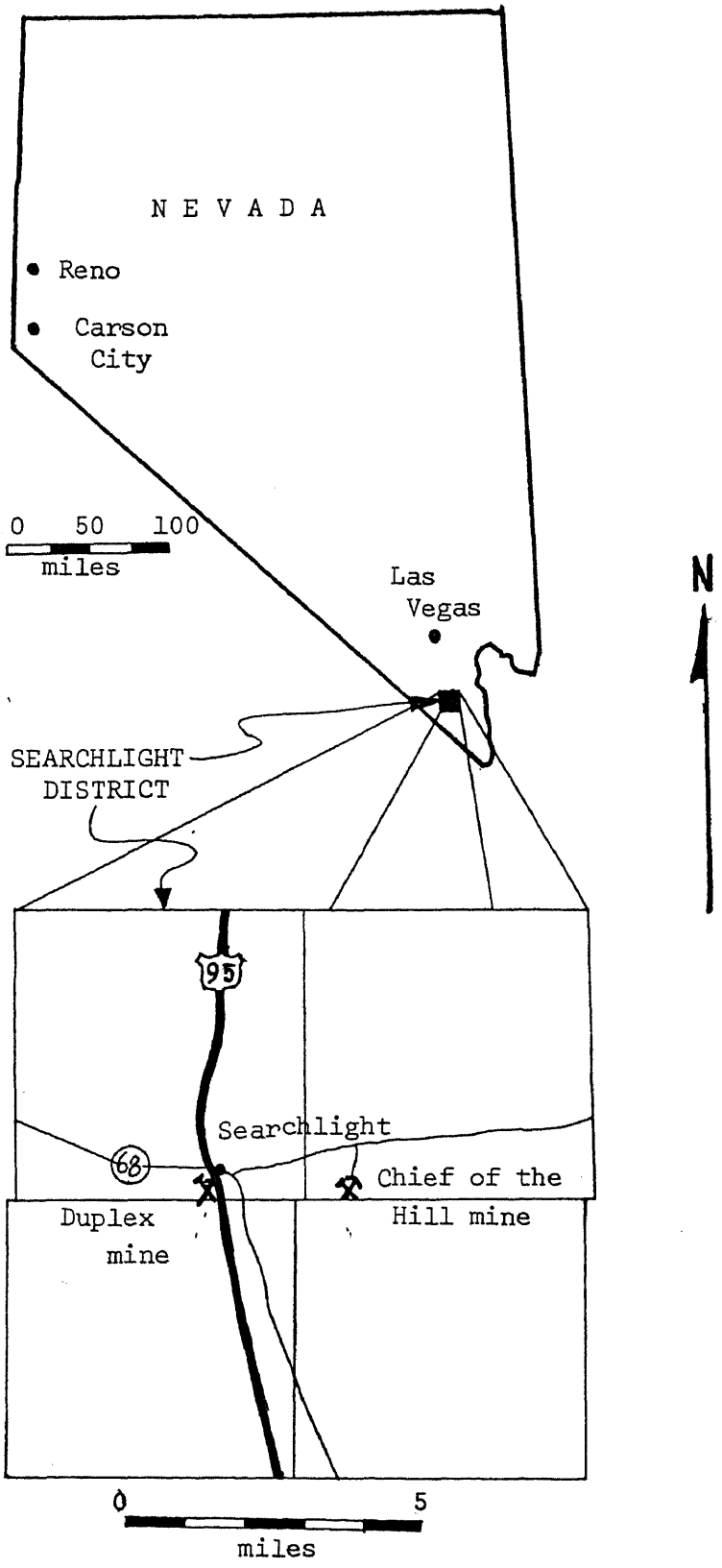

Figure 1. Location map of the area studied.

The district is accessible by roads from Las Vegas, Nevada (56 miles to the north on U.S. Highway 95) and Needles, California, which is 42 miles to the south on U.S. Highway 95.

Most productive mines are in sections 22, 27 and 34, T. 28 S., R. 63 E., and sections 2 and 3, T. 29 S., R. 63 E. The mining district was initially discovered in 1897, and has a recorded production of about $7,000,000. Most of the production has come from the Duplex and Quartette Mines.

C. Physiography

The Searchlight District may be described as a group of low hills trending roughly north-south. Pediments (Callaghan, 1939), are well developed in many places along the base of the mountains (hills) and slope gently away from those bases. Most of the mines are situated in the pediments or in the gently rolling hills above them. The altitude of the town of Searchlight is about 3,500 feet and the nearby hills rise from 200 to 700 feet above the pediment surface.

This district is included in the Mohave Desert region. The climate is similar to that of the arid southwest with an annual rainfall less than 10 inches. Water supplies are obtained from the deep wells or the mine shafts. The vertical depth to the water ranges from 100 to 300 feet.

D. Sampling Procedure, Sample Preparation and Analytical Methods

Samples were collected outward from the veins into the wall rock along lines approximately normal to the trend of the veins. Each sample was pulverized using a Spex Mixer-Mill. Ninety-seven percent by weight of the powder was minus 80 mesh.

The samples were analyzed for the trace elements content using neutron activation analysis and atomic absorption spectrophotometry. The data studied through regression and correlation procedures, to evaluate the relationships existing among the trace elements and to determine the variation in the element concentration with distance.

E. Previous Work

Finlayson (1910) studied the distribution of lead, copper and zinc zlong a normal cut to the vein at the Veille Montague Company mine at Neonthead, England. The rock unit was the Great Limestone. The result of this test shows that there is a gradual decrease in the values outward from the vein.

Lovering and Morris (1952) published their two part paper about the supergene and hydrothermal dispersion of the metals in the wall rock ore bodies in the Tintic District, Utah. Lovering in the first part determined the relative distance of the migration of the metals in moist carbonate and silicate wall rock (quartz monzonite) under the conditions existing in the past 25 years. He concluded that the important factor influencing this migration is the pH of migrating solutions.

Morris, in part 2, studied the primary dispersion patterns of Cu, Pb, Zn in the quartz monzonite and the dolomite which are the wall rocks of the veins in the Tintic District. His results from the quartz monzonite indicate that the trace elements decrease logarithmically with the distance outward from the vein which suggests that the migration was by diffusion. However, his conclusion was based on only a few samples. Also, he found that the dispersion patterns in the dolomite were restricted to an extension of 10 feet only. The dispersion patterns of Zn, Pb and Cu in the oxidized wall rock are similar to those of the primary patterns at 700 feet depths.

Jedwab (1956) analyzed 41 samples collected from two mica-rich granites from two massifs of the Morbihan region, France. The results show that the trace element content of the massif with the mineralized veins is different from the one without mineralization. This suggests that the trace elements of the granite may be used as a guide for prospecting of the mineralized areas.

Ginzburg (1960) stated that the penetration of metals by diffusion is limited to a few meters. Migration of the elements in the wall rock is due chiefly to infiltration.

Shrivastava and Proctor (1962) studied the distribution of the trace elements in the Searchlight quartz monzonite district, Nevada. They noticed that Pb and Cu occur in spatially related parallel veins.

Derews (1967) reported that the area of a Jurassic granite northwest of Patagonia, Arizona which was altered in Pliocene time, contains anomalous amounts of Cu, Pb, Zn, Au and Ag. It is assumed that the ore metals were introduced during the alteration.

Cornwall, Lakin, Nakaga and Stager (1967) analyzed 450 samples for silver, mercury and gold. Samples were collected from fresh and altered rocks in two silver-gold bonanza districts, Comstock and Tonopah, Nevada. They show that the silver and mercury anomalies delineate areas of principle silver veins in the districts.

A preliminary study was done by Alber and Ashly (1967 and 1968) on the distribution of the trace elements along a new cut across the Combination-January veins in the Goldfield District, southwestern Nevada. They show that the samples from the altered dacite are enriched in lead, silver, copper, molybdenum, bismuth and zinc and are depleted in beryllium, manganese, cobalt and nickel relative to unaltered dacite. Also, they found that lead, silver, and bismuth correlate positively with the gold.

F. Acknowledgements

The author wishes to thank his advisor, Dr. Ernst Bolter for his supervision of the research and collection of the samples. Also, Dr. John Rockaway for his help in the statistical analysis, Dr. S. K. Grant for his valuable advise during the research, and Francis Fitzgerald for supplying some geological information.

The author would like to express his appreciation to the personnel of the University of Missouri-Rolla and University of Missouri-Columbia Nuclear Reactors.

This study was supported by the National Science Foundation through NSF Grant GA-648.

II. GEOLOGIC SETTING OF THE SAMPLING AREA

A. General Statement

The oldest rock of the district is gneiss probably of Precambrian age (Callaghan, 1939). It occurs in the southern part of the district and is overlain by igneous rocks of presumed Tertiary age. The oldest volcanic ranges in composition from latite to andesite and is cut by dikes and masses of andesite porphyry. The quartz monzonite is the most extensive rock in the district, and intrudes the earlier volcanic rocks. Following the intrusion of the quartz monzonite, the andesite-latite was altered to hornfels (Callaghan, 1939). Later fracturing of the earlier rocks around the margin of the quartz monzonite allowed the introduction of the ore-forming solutions near the contact. A post-mineral series of lava flows and volcanic breccia lies on the eroded surfaces of the quartz monzonite and the older rocks.

B. Types of Wall Rock

1. Older Volcanic Rock (Duplex Mine)

According to Callaghan, 1939, "These rocks were probably deposited on the erosion surface, part of which undoubtedly cut on the gneiss, which is much older". The older volcanic rocks range from latite to andesite in composition. The wall rock of the veins in the Duplex Mine are made up of the older volcanic rocks.

In general, these rocks were altered to hornfels after the intrusion of the andesite porphyry and the quartz monzonite. However, the wall rock of the Duplex Mine and some other areas were not much affected by the intrusion.

In thin section, these volcanics are very fine-grained, dark to gray, highly altered rocks, after the introduction of the ore-forming solution. Most of the original minerals are not recognisable except as a few phenocrysts of plagioclase which are partially preserved. A few grains of biotite (recognized by shape) are altered to chlorite. There are also a few grains of highly altered orthoclase. Epidote is scattered through the rock mainly as veinlets associated with quartz, calcite (rarely), magnetite and other iron oxides.

2. Andesite Porphyry (Chief of the Hill Mine)

The andesite porphyry is the wall rock of the Chief of the Hill vein. It has intruded the older volcanic rocks in a most complex fashion as dikes, sills, and masses having irregular margins. The rock is brownish on weathered surfaces and gray in the wall rock of the underground workings. In thin sections, the rock is porphyritic, with euhedral to subhedral phenocrysts of oligoclase, and altered crystals of biotite and hornblende, embedded in the ground mass which is mainly fine-grained plagioclase and magnetite accompanied with other minerals. The alteration products are clay-like minerals (kaolinite) mostly after plagiocalse, chlorite (after biotite), epidote and minor amounts of sericite.

The andesite porphyry and the older volcanic rocks have been intruded by the quartz monzonite. The andesite porphyry is the early facies of the quartz monzonite and represents the first magma which penetrated into the thin rock cover, followad by the other magma which had sufficient cover to cool as quartz monzonite (Callaghan, 1939).

3. The Veins

The veins are in the fractured zone of the volcanic rocks around the margin of the quartz monzonite. Most of the vein areas are distributed to the west of the monzonite (Duplex Mine) and few of them to the far east (Chief of the Hill). The veins which were analyzed for the metal content are desdribed as follows:

a. Chief of the Hill Vein

The Chief of the Hill vein is on a ledge known as the Fourth of July Mountain, south of the Kingman Ferry Road, three miles east of Searchlight, Nevada. The vein strikes N. 85° W., and dips 90° approximately. The materials of the vein are breccia of the wall rock cemented by the vuggy comb quartz (Callaghan, 1939) and the orange tinted calcite which fills some cavities. The wall rock is andesite porphyry. This vein is mined mainly for gold and silver.

b. "New Year's Gift" and "Fraction" Veins of the Duplex Mine

The Duplex Mine is on the hill south of Searchlight. Those two veins which are the most productive were sampled. The

veins cut the older volcanic rocks (andesite-latite) outside the quartz monzonite. The veins are cut by shear planes and faults of moderate displacement (mainly normal faults) and they strike N. 57° W. approximately, and dip gently 25° to the south. The veins are mainly brecciated fragments of the wall rock cemented with the comb quartz. The ore occurs in lenses in the veins. The veins are oxidized as far as mining development has gone, but residual lumps of galena are scattered through the ore shoot. The main products are silver and gold which occur in 1:1 proportion (Ronsom, 1907). The main lead minerals are cerussite and galena. Copper occurs as chalcocite, azurite and malachite. Zinc occurs as hemimorphite (calamine)(Ronsom, 1907). Other minerals occurring in the veins are pyrite and calcite.

4. Wall Rock Alteration

The wall rock of the different veins shows a wide variation of alteration. In the Chief of the Hill Mine the adjacent andesite porphyry has not undergone a large amount of alteration, since the phenocrysts of plagioclase in the wall rock are fairly preserved. On the other hand, the effect of the ore forming solution was rather strong near the Duplex Mine. It appears that the wall rocks (old volcanic) are changed to a clay-like aggregate, mainly kaolinite(?) accompanied with the other alteration products in the vicinity near the vein. From the veins outward the zones are clay minerals (mainly kaolinite) followed by the porphylitic assemblage (epidote, chlorite, and

carbonates with iron oxides and minor amounts of sericite). These alteration patterns are similar to those described by Harvey and Vitalino (1964) in the andesitic volcanics at Goldfield, Nevada.

III. SAMPLING AND SAMPLE PREPARATION

A. Sampling Procedure

Three hundred and twenty-seven samples were collected from Searchlight, Nevada. The samples of "series" A, B, C and D were collected from the Chief of the Hill Mine and samples of "series" E, F and G were collected from the Duplex Mine.

The samples of "series" A and B were collected from the surface rocks from Fourth of July Mountain. Line A is to the south, and line B is to the north, approximately normal to the vein. The samples of the "series" C and D, Fig. 2 (See Map of Chief of the Hill Mine underground) were collected from two underground cuts approximately along two lines normal to the vein. Line C represents the long cut samples and line D represents the short cut samples. The vein strikes N. 85 W. or nearly at right angles to the ridge and dips 85° NE and it is about 6-10 feet wide.

The samples of "series" E and F were collected from the fifth level of the Duplex Mine, Nevada, Fig. 3 (See Map of the Duplex Mine underground), along two lines approximately normal to the "New Year's Gift" vein. Line E samples were collected from the hanging wall and line F in the foot wall. The samples of "series" G (Fig. 4, Map of Duplex Mine) were collected from the sixth level of the Duplex Mine along a line normal to the "fraction" vein in a direction to the south. The veins strike N. 57 W. and have an average dip of 27° W.

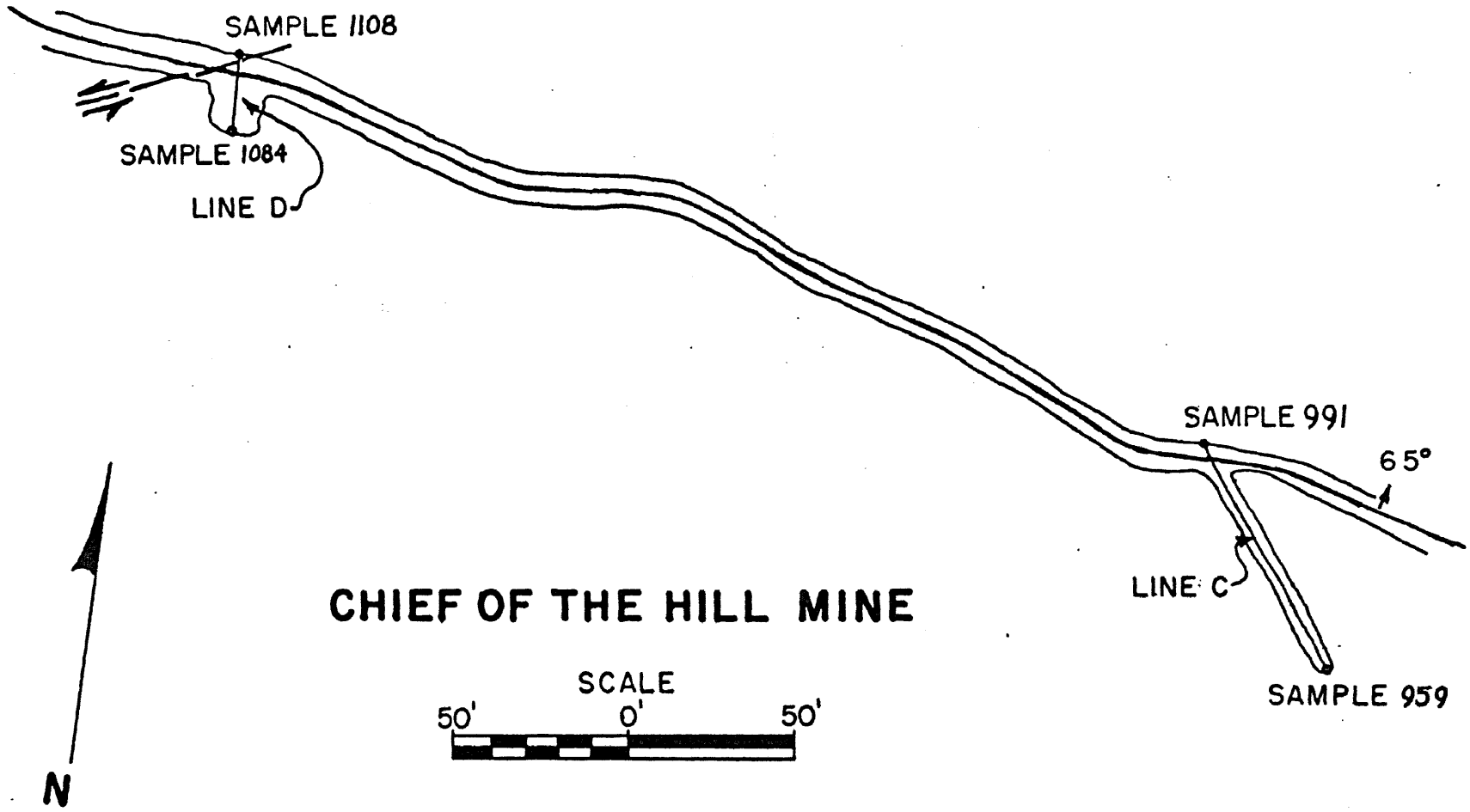
SAMPLE 1108
SAMPLE 1084
LINE D
SAMPLE 991
65°
LINE C
SAMPLE 959
CHIEF OF THE HILL MINE
SCALE
50'
0'
50'
N

FIGURE 2

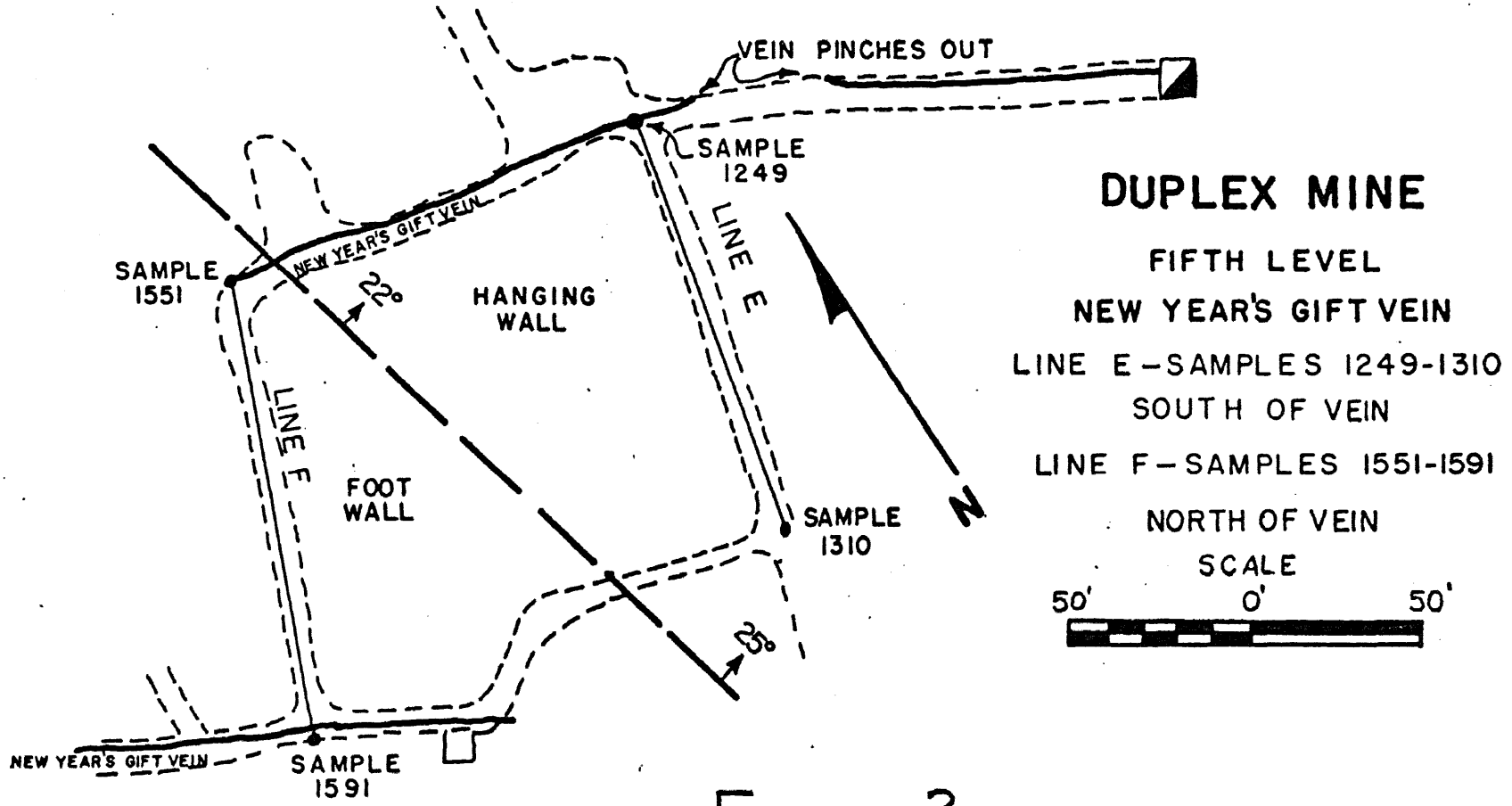
VEIN PINCHES OUT
SAMPLE 1249
LINE E
NEW YEAR'S GIFT VEIN
SAMPLE 1551
22°
HANGING WALL
LINE F
FOOT WALL
SAMPLE 1310
N
35°
NEW YEAR'S GIFT VEIN
SAMPLE 1591
DUPLEX MINE
FIFTH LEVEL
NEW YEAR'S GIFT VEIN
LINE E - SAMPLES 1249-1310
SOUTH OF VEIN
LINE F - SAMPLES 1551-1591
NORTH OF VEIN
SCALE
50' 0' 50'

FIGURE 3

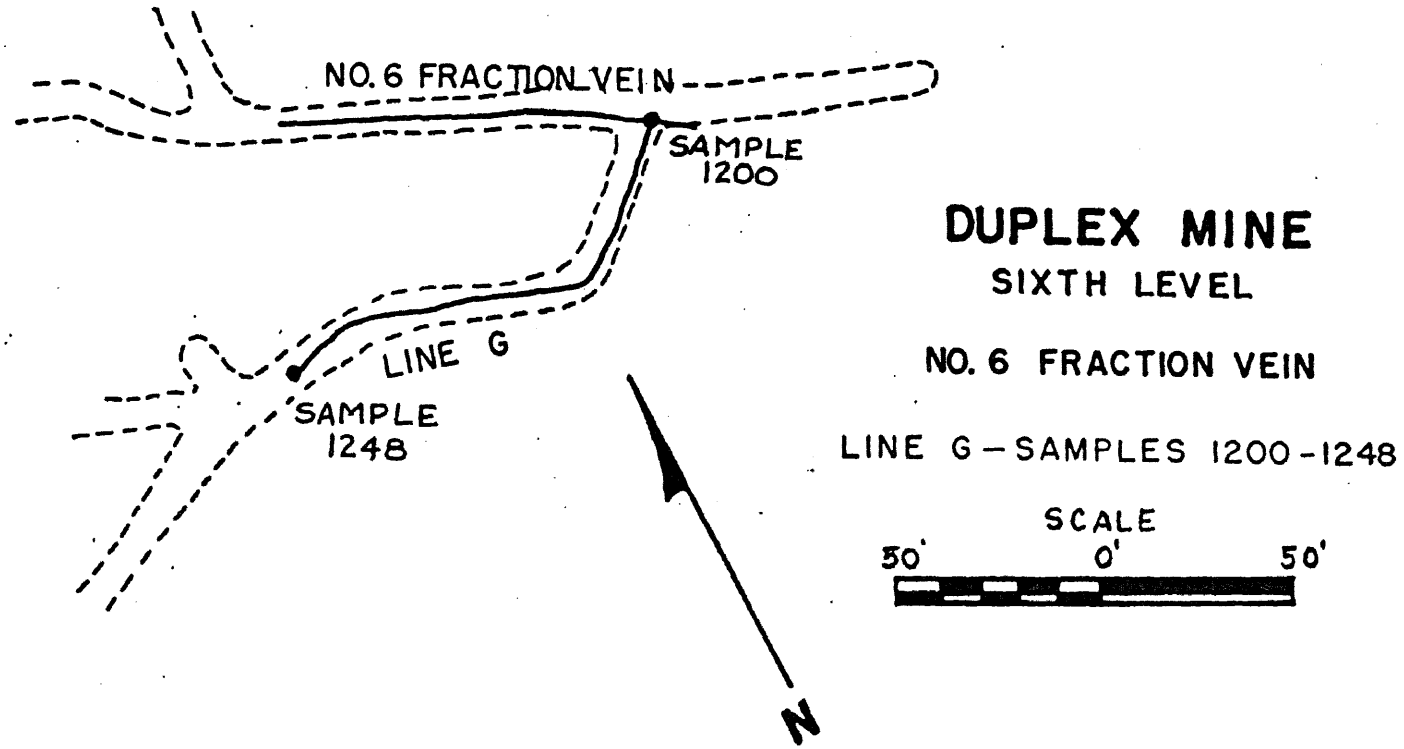
NO. 6 FRACTION VEIN
SAMPLE 1200
LINE G
SAMPLE 1248
N
DUPLEX MINE
SIXTH LEVEL
NO. 6 FRACTION VEIN
LINE G – SAMPLES 1200 - 1248
SCALE
50' 0' 50'

FIGURE 4

The samples of A, B, C, D, E, F and G were collected in short intervals along approximately 100 feet. Sample intervals were 1 foot for the first 40 feet and then 5 feet for the remainder. In cases where the sampling line is not normal to the edge of the vein the distances were recalculated for normal distances to the vein.

B. Sample Preparation

Each sample was washed with distilled water and cut into slices with a diamond saw. The outer part of the rock slices were removed with a hammer. The remaining "inner" parts of the rock slices were crushed and pulverized using a Spex Mixer-Mill which is a high speed ball mill made of steel with balls of the same material. Of the resulting powder, 97% by weight had a grain size of less than 80 mesh. Ground samples were stored in wide-mouth glass bottles. Removal of the outer portions of the rock pieces eliminated possible contamination through dust from vein material.

IV. CHEMICAL ANALYSIS

The samples of the Searchlight area (veins and volcanic wall rocks) were analyzed for gold, silver and selenium by neutron activation analysis and for copper, lead, zinc, molybdenum and arsenic by Atomic Absorption Spectrophotometry.

A. Neutron Activation Analysis

The detection of minute quantities of trace elements by neutron activation analysis has become increasingly popular within the past decade. When a target material is exposed to neutron bombardment a nuclear reaction and product decay occurs as follows:

$$A \xrightarrow{n} B \xrightarrow{\lambda b} C$$

The stable isotope, A, being bombarded by a neutron is transmuted to radionuclide B, which decays with its characteristic disintegration constant λ_b, to the stable isotope C.

Thermal neutrons (<0.4 rev) are preferred in the reaction above because of a minimum number of competing reactions which are possible. Also, most elements have a relatively high thermal cross section, self-shielding effects are less pronounced, and many samples can be irradiated simultaneously. The most intense neutron sources have been provided by nuclear reactors utilizing the fission reaction. Fluxes now available are of many orders of magnitude and thus the sensitivity of neutron activation analysis may be increased to a large degree.

Neutron activation analysis has found wider applications in the determination of trace constituents in geochemical samples as it has become possible to separate small amounts of active components from the complex and highly active matrix by chemical techniques. Corrections can be made for losses that may occur during chemical processing.

The most widely used measuring technique in activation analysis is the gamma-ray spectrometry. This generally involves absorption of the gamma-ray by a sodium iodide crystal and then the processing the pulse with a multi-channel analyzer.

Neutron activation analysis is well suited to the determination of traces of gold and silver in various materials because of the high sensitivity which can be attained using this method.

1. Gold Analysis

Gold is a mono-isotopic element and by activation with thermal neutrons the following nuclear reaction occurs:

$$Au^{197} (n, \gamma) Au^{198}$$

half life T 1/2 = 2.7 days

cross section σ = 96 barns

B = 0.96 Mev

γ = 0.41 Mev

From this data it follows that under suitable conditions (irradiation in a flux of 10^{12} neutrons cm^{-2} sec^{-1} saturation activity) using

radiochemical separation it is theoretically possible to determine gold down to 10^{-11}g.

The samples used for gold analysis were sealed in polyethylene vials along with a gold standard and sluminum flux monitor having constant Cr^{51} impurity. The samples were activated for 10 hours in a flux of 10^{12} cm^{-2} sec^{-1} in the U.M.R. Nuclear Reactor. The samples were allowed to decay for 4 days to reduce the activity of short-lived nuclides, e.g. Na^{24}, before the radiochemical separation procedure.

a. Reagents

All reagents were analytical grade chemicals. A 0.03g gold carrier was prepared by dissolving 6.12g of $HAuCl_4.3H_2O$ (49% Au) in 100 ml distilled water. Five percent hydroquinon was prepared by dissolving 5g of hydroquinon in 100 ml distilled water.

b. Procedure

To a 1.00g powder rock sample in a teflon beaker was added 30 ml of 48% HF and 0.030 gram pipetted portion of gold carrier. The contents were digested to near dryness on a hot plate. A modified method by Goldberg and Brown (1949) was used as follows. To the digested contents 10 ml aqua regia was added. The teflon beakers were covered, the contents were digested again to near dryness. After cooling, 30 ml of 25% HCl was added and the liquid contents transferred to a 125 ml separatory funnel. Thirty ml ethyl acetate was added to the separatory funnel contents and the funnel was shaken for 60 seconds. After separation the

aqueous layer was drained and discarded as radioactive waste. The organic layer was then washed twice with 30 ml portions of 10% HCl. The purified organic layer was evaporated on a hot plate to dryness. Twenty ml of 15% HCl was then added and followed by 10 ml of 5% hydroquinon. The solution was brought to boiling on a hot plate. The precipitated (reduced) gold was filtered through preweighed analytical filter paper and washed with 10 ml hot water and with 10 ml ethyl alcohol. The filter paper was dried at 100°C and weighed. The chemical yield was calculated. The chemical yield was usually around 70 percent.

2. Silver Analysis

Silver is an di-isotopic element and by its activation with a thermal neutron the following nuclear reactions occur.

$$^{109}Ag \quad (n,\gamma) \quad ^{110}Ag$$

half life $T_{1/2}$ = 270 days

cross section σ = 80 barns

β = 287 Mev

γ = 0.447, 0.659 and 0.883 Mev

From this data it follows that under suitable conditions (irradiation in a flux of 10^{14} neutrons cm^{-2} sec^{-1}) with radiochemical separation it is theoretically possible to determine silver down to 1 ppb.

The samples used for silver analysis were wrapped in aluminum foil with a flux monitor (Al with a Cr^{51} impurity) along with an Ag standard and were placed in aluminum containers for activation

at the University of Missouri-Columbia Nuclear Reactor. The samples were irradiated for 24 hours in a thermal flux of $1x10^{14}$ cm^{-2} sec^{-1}. After a decay period of two weeks, to reduce the activity of short lived nuclides the samples were radiochemically separated as follows.

a. Reagents

All reagents used were analytical grade chemicals. A 0.03g carrier was prepared by dissolving 4.722g of $AgNO_3$ in 100 ml distilled water, 1% Fe solution (scavenger) was prepared by dissolving 1g of Fe metal in 20 ml concentrated HCl. After filtering the solution is diluted to 100 ml with distilled water.

b. Procedure

A 1.0g powdered rock sample was treated the same way as gold but with the addition of 30 ml of 25% HCl. Then the liquid was drained and discarded as radioactive waste and the precipitated silver chloride in the teflon beaker was washed with 20 ml of 10% HCl and 5 ml of NH_4OH was added. The contents were then transferred to a 50 ml centrifuge tube. One drop of $FeCl_3$ was added as a scavenger. The samples were centrifuged. The liquid portion was transferred to a 50 ml beaker and the silver chloride was precipitated with 10 ml concentrated HNO_3. The AgCl was filtered through preweighed filter paper and dried at 110°C. The chemical yield was calculated. The yield was usually between 75 and 80 percent.

3. Selenium Analysis

Selenium has 6 isotopes. By activating it with a thermal neutron source the following nuclear reaction occurs.

$$Se^{74} \quad (n,\gamma) \quad Se^{75}$$

half life $T_{1/2}$ = 120 days

cross section σ = 30 barns

γ = 0.136, 0.265 and 0.905 Mev

Powdered rock samples of 1.0g were wrapped in aluminum foil along with a flux monitor (aluminum containing Cr^{51} impurity) and irradiated for 24 hours in a thermal neutron flux of $1x10^{14}$ Sin^{-2}/sec^{-1} in the reactor at the University of Missouri-Columbia. A selenium standard consisting of 0.1 ml of a solution prepared by dissolving SeO_2 in dilute nitric acid (1 m se/ml) sealed in aluminum foil, was irradiated together with the samples. After seven days decay, to reduce the activity of the short-lived nuclides the samples were transferred to . teflon beakers containing 1 ml selenium carriers (30 mg se). Thirty ml of 45% HF and 10 ml of nitric acid were added and the contents were digested to dryness on a hot plate. The beaker contents were washed with 1 ml water. The temperature of the beakers was raised, and 5 ml of concentrated HNO_3 and 10 ml of water were added. The solution was boiled until clear. A method by Brunfelt and Steinnes (1967) was used to extract selenium.

Au^{198} and Ag^{110} and Se^{75} were counted by using a 400-channel analyzer spectrometer model 34-27 (Nuclear Chicago) equipped with two 3x3" hoarshaw NaI(Tl) crystals inside a lead shielf 4 inches thick.

The 400-channel analyzer is attached to an IBM typewriter for data output. All data were compiled and a Fortran language computer program was used for the calculations at the U.M.R. Computer Center.

B. Atomic Absorption Spectrophotometry

1. Theory

Atomic absorption is a method which determines the concentration of metallic and semi-metallic elements in solution. The method is based on the fact that each element, when in its atomic state, can absorb light at specific wavelengths. Sample elements are reduced to their atomic state by burning them in a flame. Light from a hollow cathode lamp, which emits the spectrum of the element of interest is passed through the flame and the degree of absorption is measured. The number of atoms capable of absorbing any transmitted light of appropriate wavelength is proportional to the product of the concentration of these atoms in the flame and the length of the light through the flame.

A Perkin-Elmer model 303 double-beam atomic absorption spectrophotometer was used for the analysis of copper, lead, zinc, arsenic and molybdenum in the samples. The Perkin-Elmer 303 was operated with a Air-Acetylene flame and was equipped with a "Premix" type burner. The chamber of this burner is made of inert penton plastic, so that cross contamination of samples has not been a problem. The Perkin-Elmer flame is not very luminous, and turbulence is quite low, so that for many elements, the flame contributes no apparent noise to the output. The

commercial readout device DCR-1 is used as an accessory to the model 303. Also the Servo/riter recorder which is a self-balancing potentiometric strip chart recorder was used.

2. Reagents

All reagents were analytical grade chemicals. The water was demineralized by ion exchange and then was distilled in a distillation apparatus.

3. Standard

Standard stock solutions of 10,000 ppm copper, lead, zinc, arsenic and molybdenum (Fisher) were diluted to 100, 50, 10, 5, 3, 1, 0.7, 0.5, 0.3 and 0.1 ppm.

4. Procedure

To 1.0g of powdered rock in a 100 ml teflon beaker 30 ml of 48% HF, and 10 ml of concentrated HNO_3 were added. The solution was allowed to stand for 2 hours. Two milliliters of 70% $HClO_4$ were added and fumed until no more white fumes came off. The beaker was washed with 1 ml of water and taken to dryness. The temperature of the beaker was raised slightly, 5 ml of concentrated HNO_3 were added, and the solution was brought to a boil. When all solids were dissolved, 25 ml of water was added slowly while boiling. The solution was boiled until clear, and transferred to 50 ml volumetric flask. The solution was cooled, brought to volume and transferred to

polyethylene bottles. The dissolved samples were analyzed for Cu, Pb, Zn, As and Mo. Samples were run for 30 seconds, then the instrument was aspirated with 0.2N HCl wash solution. The instrument was rezeroed on the blank solution. Standards were run before and after each group of samples. The instrumental setting and type of lamps used are shown in the table below.

Table 8. Instrumental Settings.

Element	Range	Wavelength (Å)	Silt	Source	Current amp	Fuel Flow	Air Flow
Cu	uv	3247	4(1mm, 74)	H.C.*	15	9.0	9.0
Pb	uv	2833	4(1mm, 74)	H.C.	30	9.0	9.0
Zn	uv	2138	5(3mm, 20A)	H.C.	15	9.0	9.0
As	uv	1937	4(1mm, 7A)	H.C.	12	9.0	9.0
Mo	uv	3133	3(0.3mm, 2A)	H.C.	30	9.0	7.5

*Hollow cathode

The acetylene pressure was 8 psi and air pressure was set to 30 psi at the burner regulator.

V. RESULTS AND DISCUSSION

A. General Statement

In discussing the results obtained from the analysis in the previous chapter, the first important phenomenon to be discussed is the dispersion patterns of the different trace elements in the Tertiary volcanic rocks. The investigated veins are:

a. Quartz-gold and silver vein (Chief of the Hill Mine)

b. Quartz-gold, silver, copper, lead and zinc veins (Duplex Mine)

The intensity and extent of the trace element anomalies in the wall rock is a function of many variables such as:

1. The type of composition and the wall rock.
2. The condition of the wall rock.
3. The temperature of the ore-forming solution.
4. The concentration of the trace elements in the hydrothermal vein.
5. The duration of the hydrothermal activity.

The next step is to find trends or patterns in the dispersion of the different elements and the effect of the above variables on these patterns. Also, it is important to study the fractures in the wall rock and their effect on the penetration of the trace elements in the wall rock.

These fractures are mainly concentrated in the faulted area, which follows the intrusive deformation (Callaghan, 1939). Therefore, wall rock dispersion patterns will be affected by the orientation of the fractures.

B. Dispersion Patterns of the Trace Elements in the Chief of the Hill Wall Rock

The dispersion patterns of gold, silver, lead, copper and zinc in the wall rock will be discussed. Two hundred and seventeen vein and wall rock samples were analyzed for gold, silver, lead, copper and zinc. Chief of the Hill vein is a quartz-gold and silver vein, and the wall rock is mainly andesite porphyry (Callaghan, 1939). The values obtained from the analysis of the vein and the wall rocks are listed in Tables 1 to 4, Appendix A. Figures 5 through 25 show the distribution of the gold, silver, lead, copper and zinc in the wall rock of the vein along the lines A and B and along linees C and D (see Fig. 2).

1. Gold Dispersion Patterns

Figures 5 through 8 show the distribution of the gold in the wall rock along the sampling lines A to D. Except for samples close to the vein the surface samples show a steady decrease of the gold content till background values are reached at about 95 feet distance (line A) and 145 feet (line B). The samples from the underground lines C and B do not show the same regular decrease. Gold values vary sporadically.

2. Silver Dispersion Patterns

Figures 9 through 12 show distribution of the silver along the sampling lines A, B, C and D. The area of the heavy silver anomaly ranges up to 35-50 feet from the edge of the vein. This anomaly can be divided into two divisions.

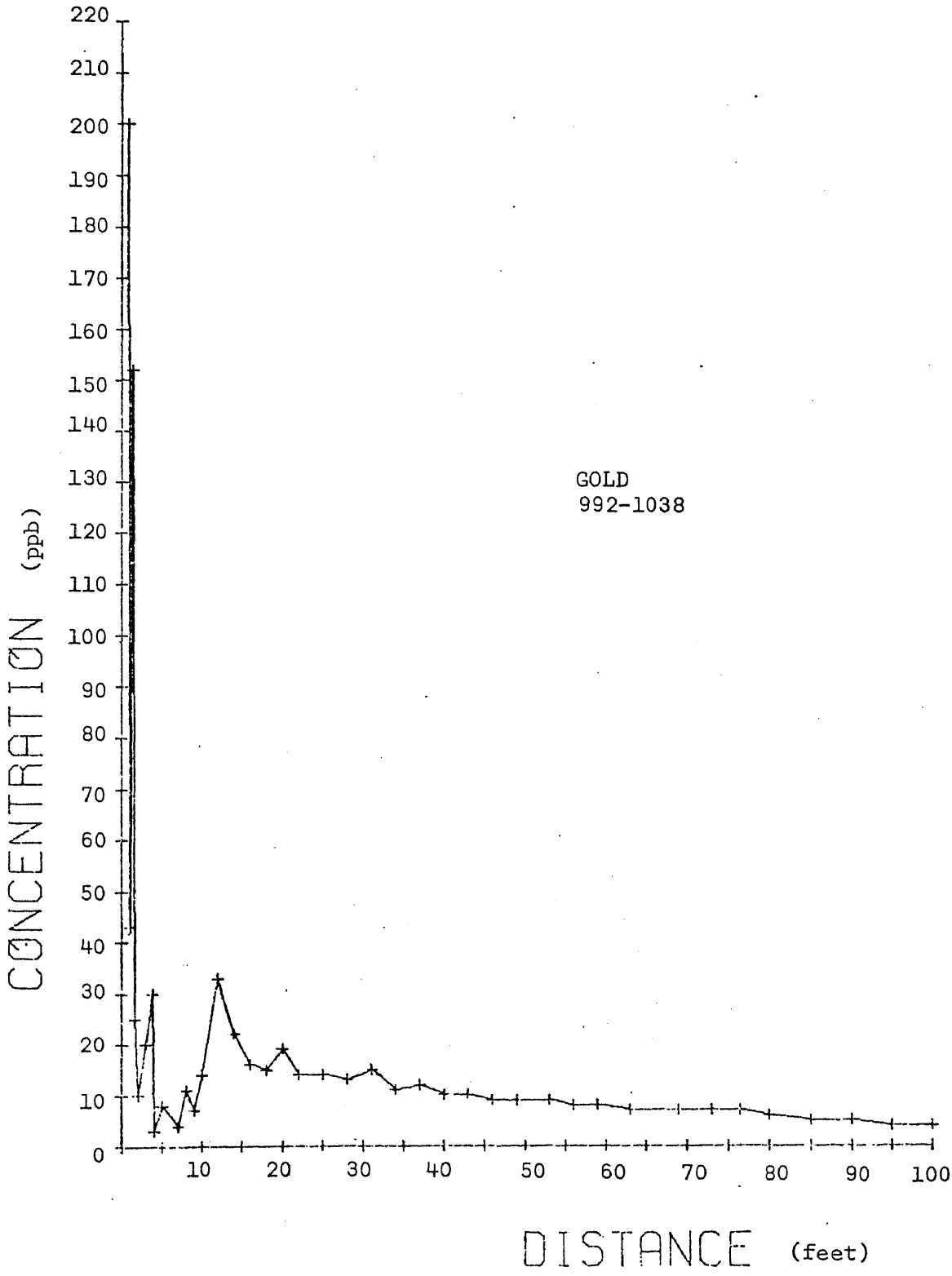

Figure 5. Gold dispersion pattern, Chief of the Hill Mine, Line A.

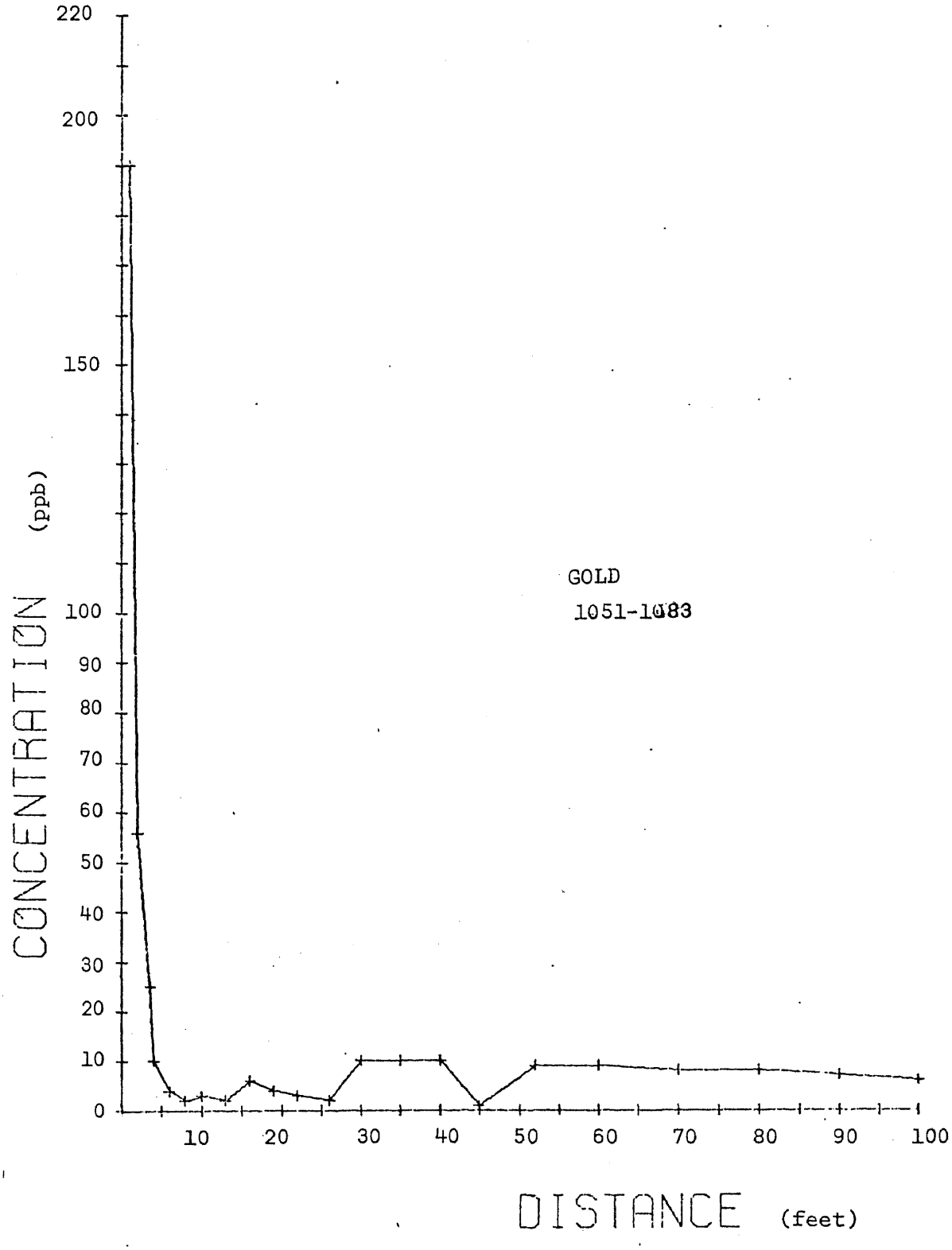

Figure 6. Gold dispersion pattern, Chief of the Hill Mine, Line B.

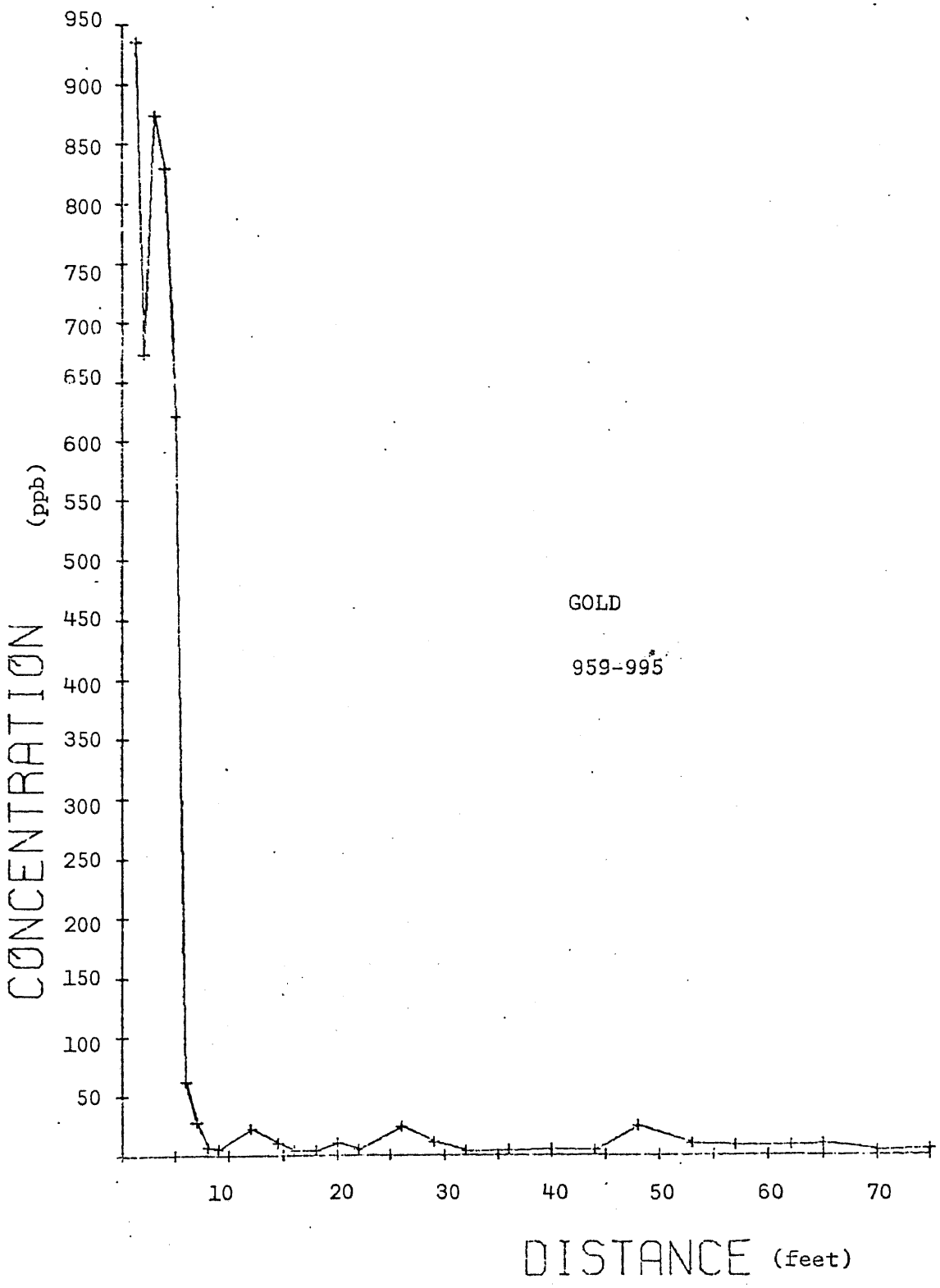

Figure 7. Gold dispersion pattern, Chief of the Hill Mine, Line C.

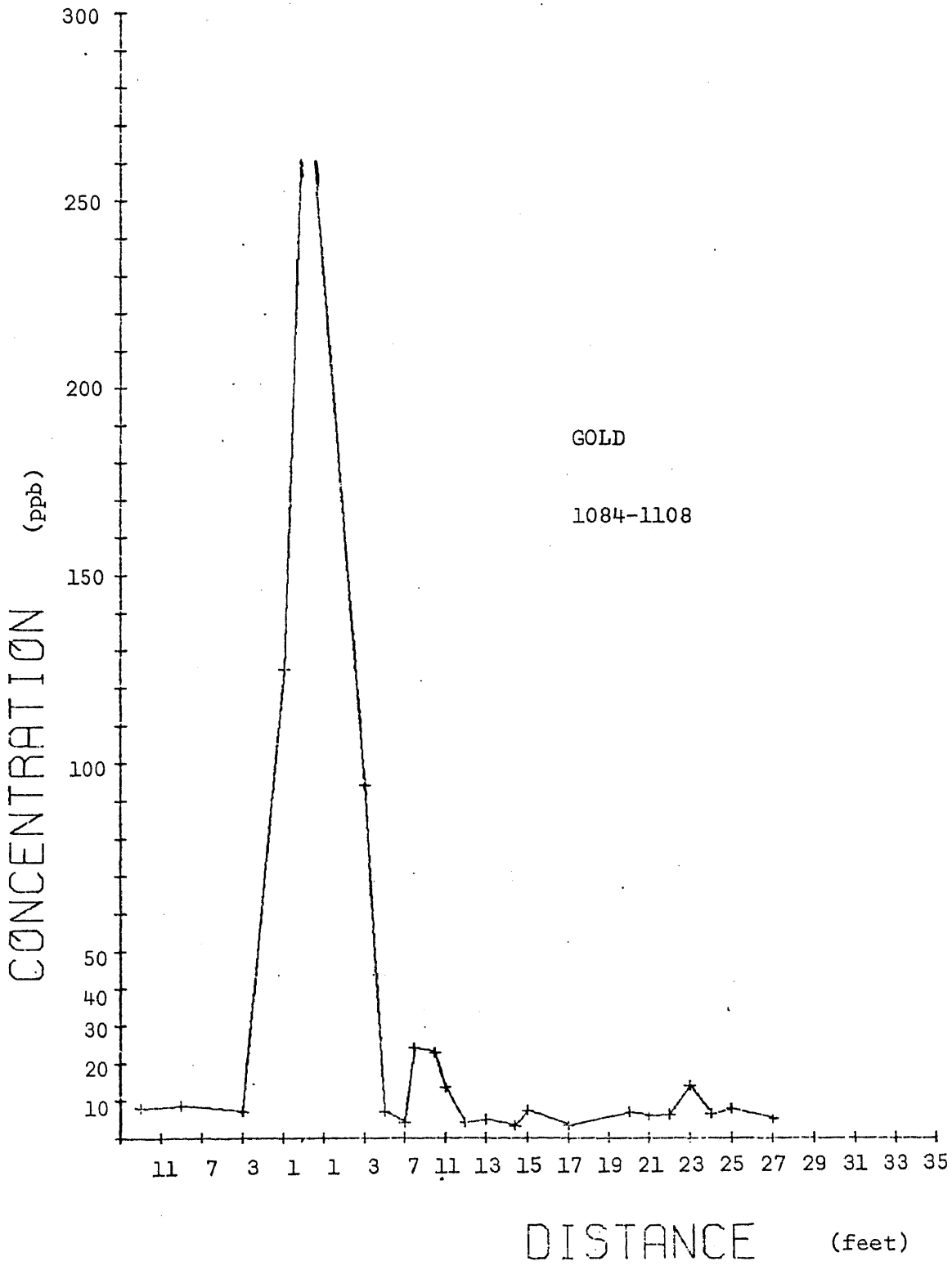

Figure 8. Gold dispersion pattern, Chief of the Hill Mine, Line D.

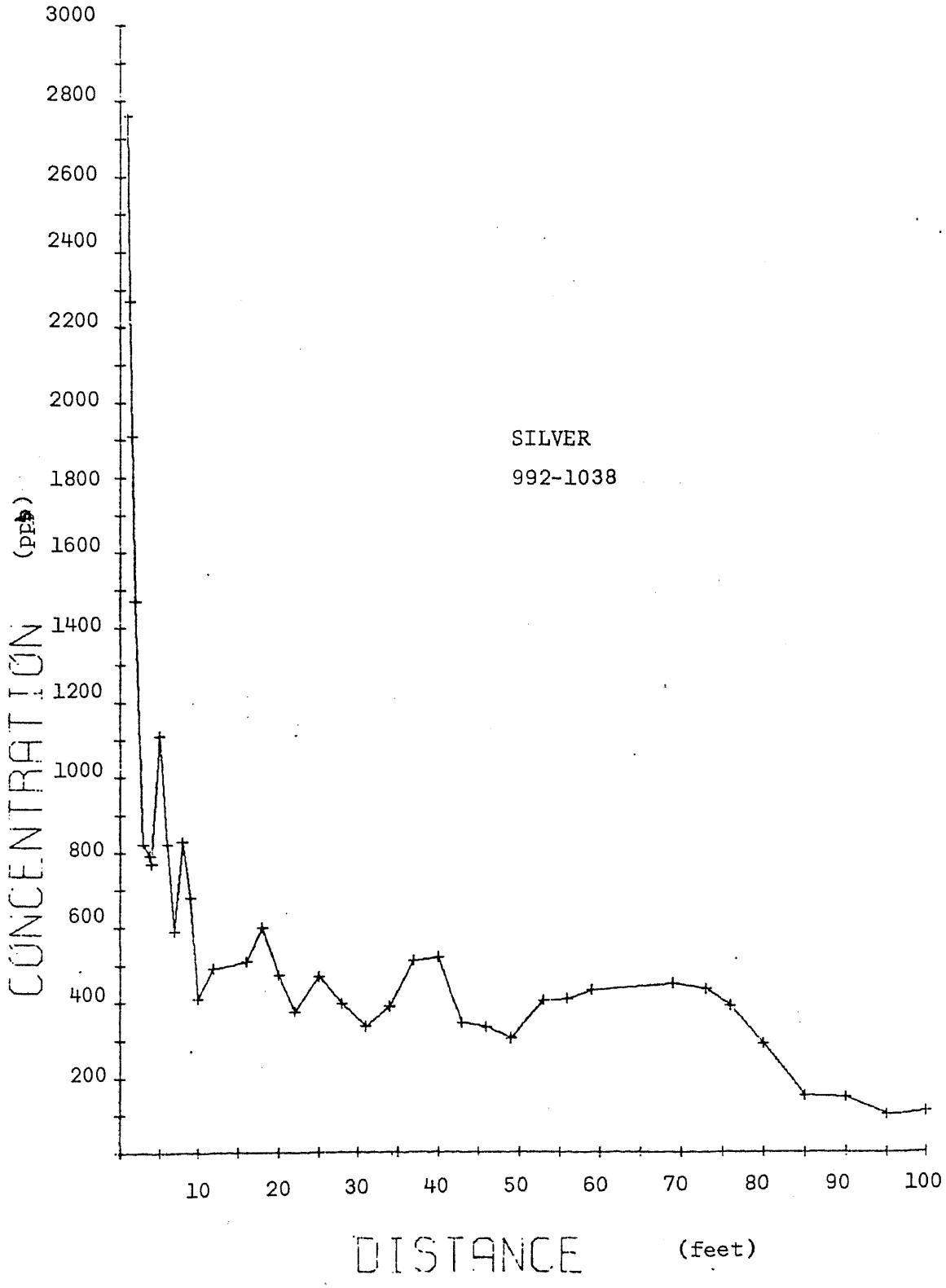

Figure 9. Silver dispersion pattern, Chief of the Hill Mine, Line A.

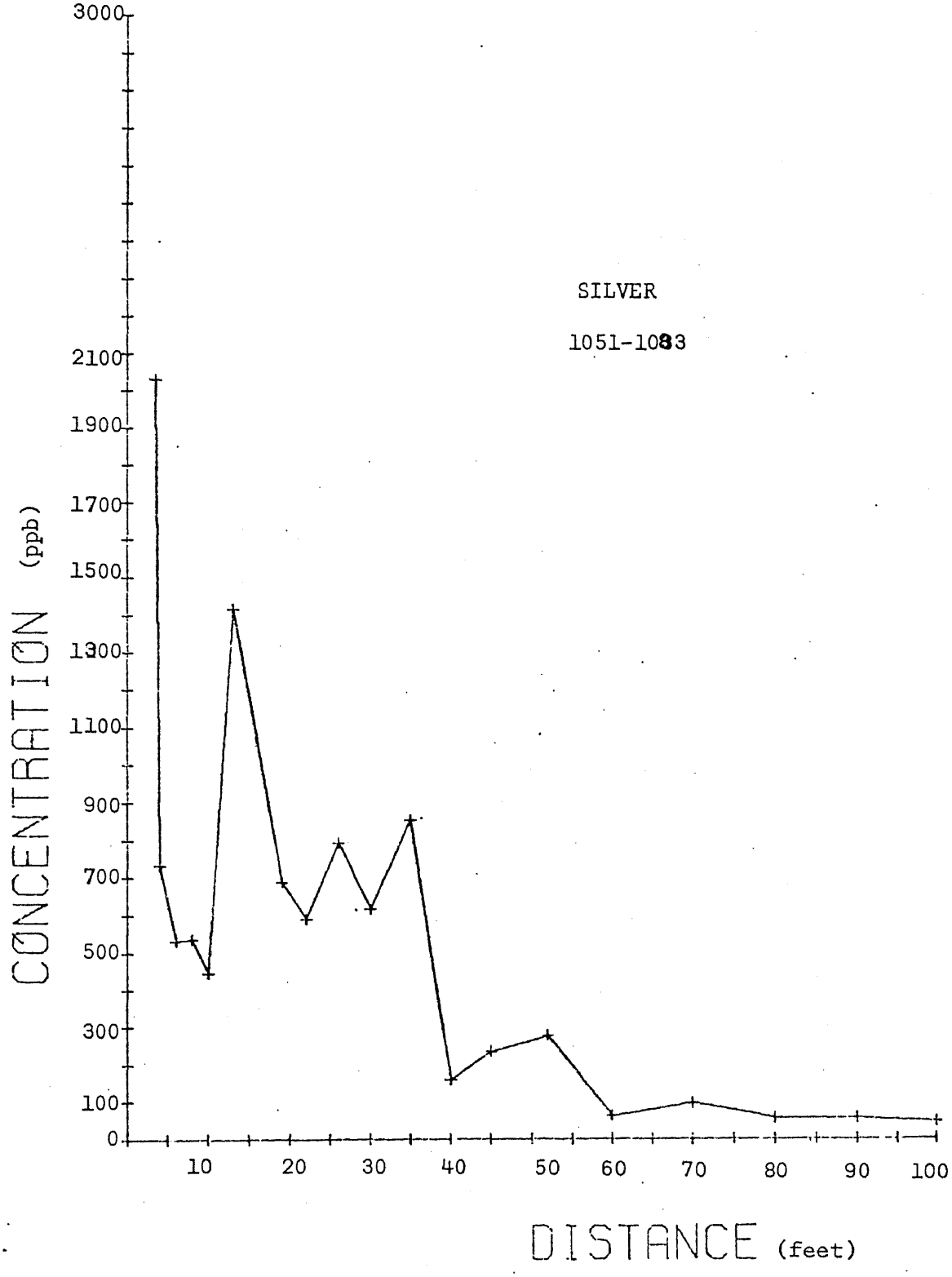

Figure 10. Silver dispersion pattern, Chief of the Hill Mine, Line B.

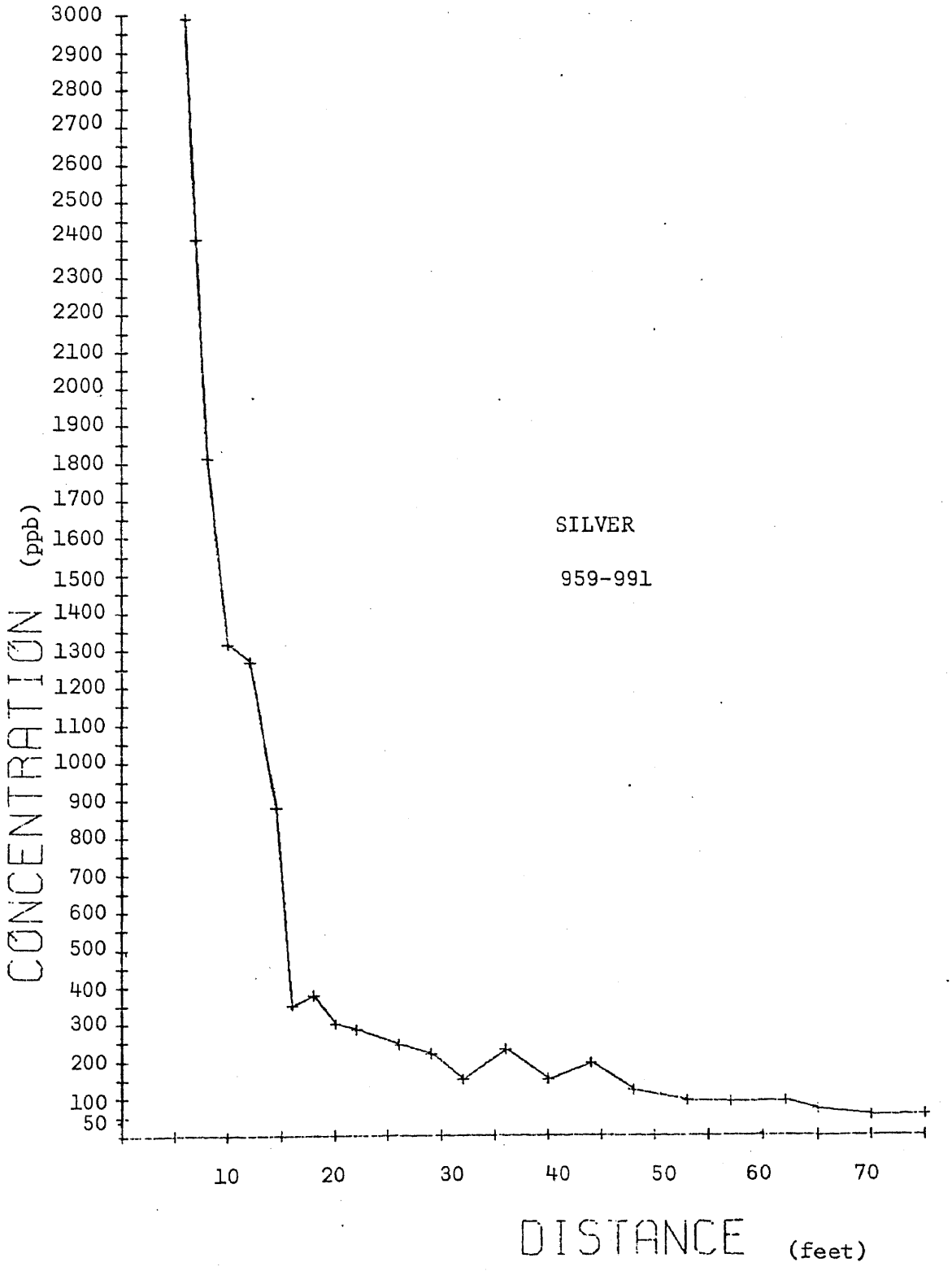

Figure 11. Silver dispersion pattern, Chief of the Hill Mine, Line C.

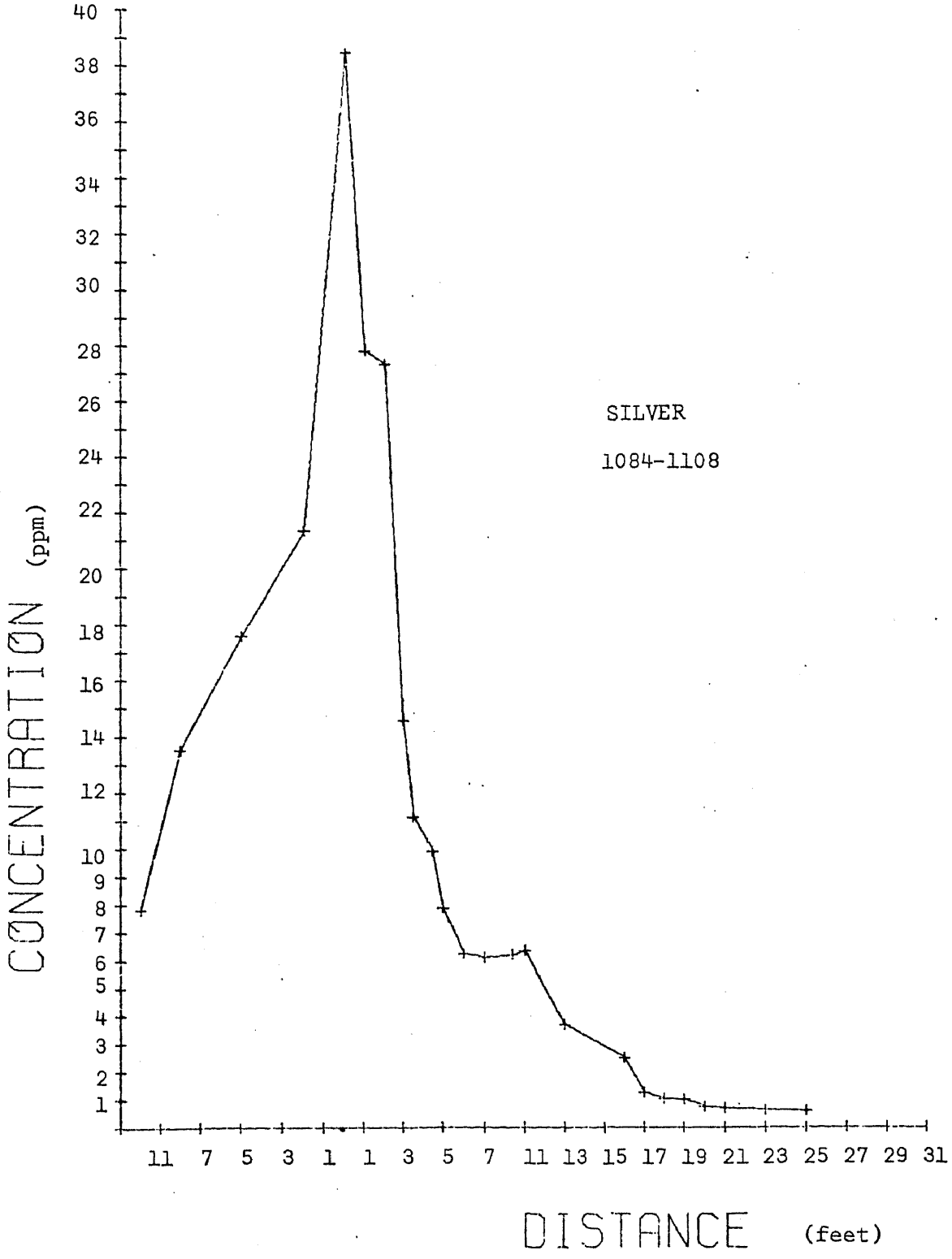

Figure 12. Silver dispersion pattern, Chief of the Hill Mine, Line D.

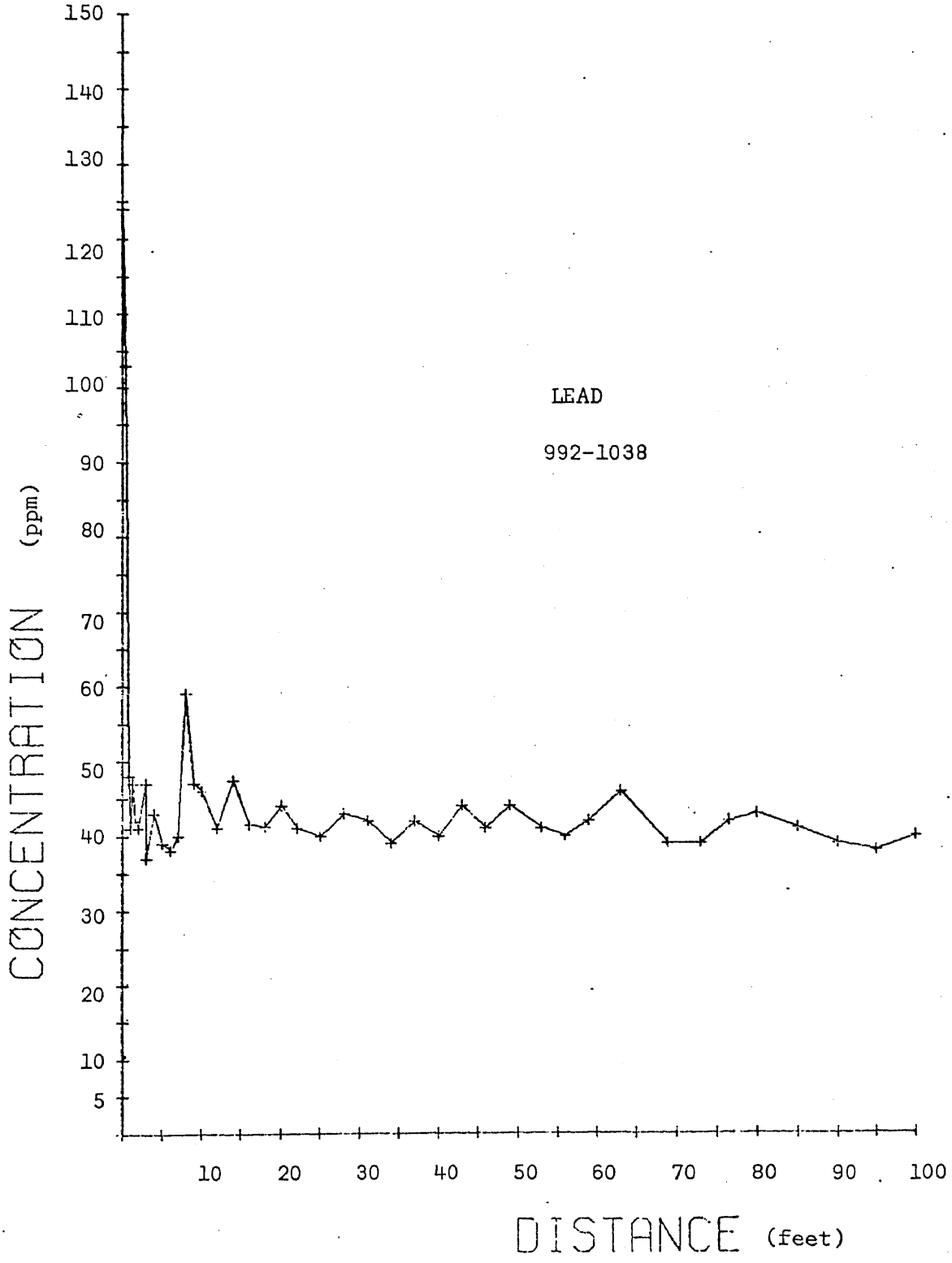

Figure 13. Lead dispersion pattern, Chief of the Hill Mine, Line A.

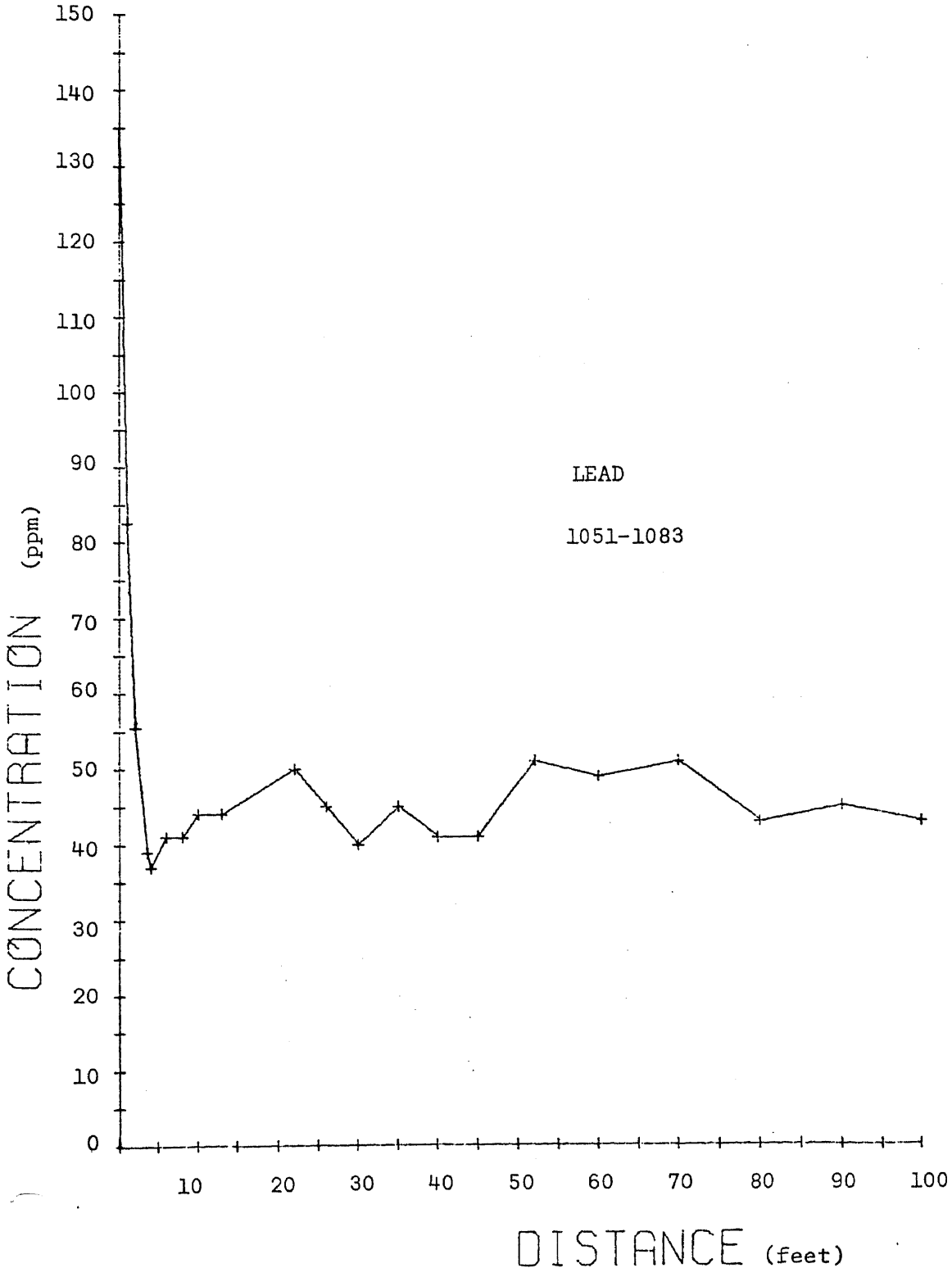

Figure 14. Lead dispersion pattern, Chief of the Hill Mine, Line B.

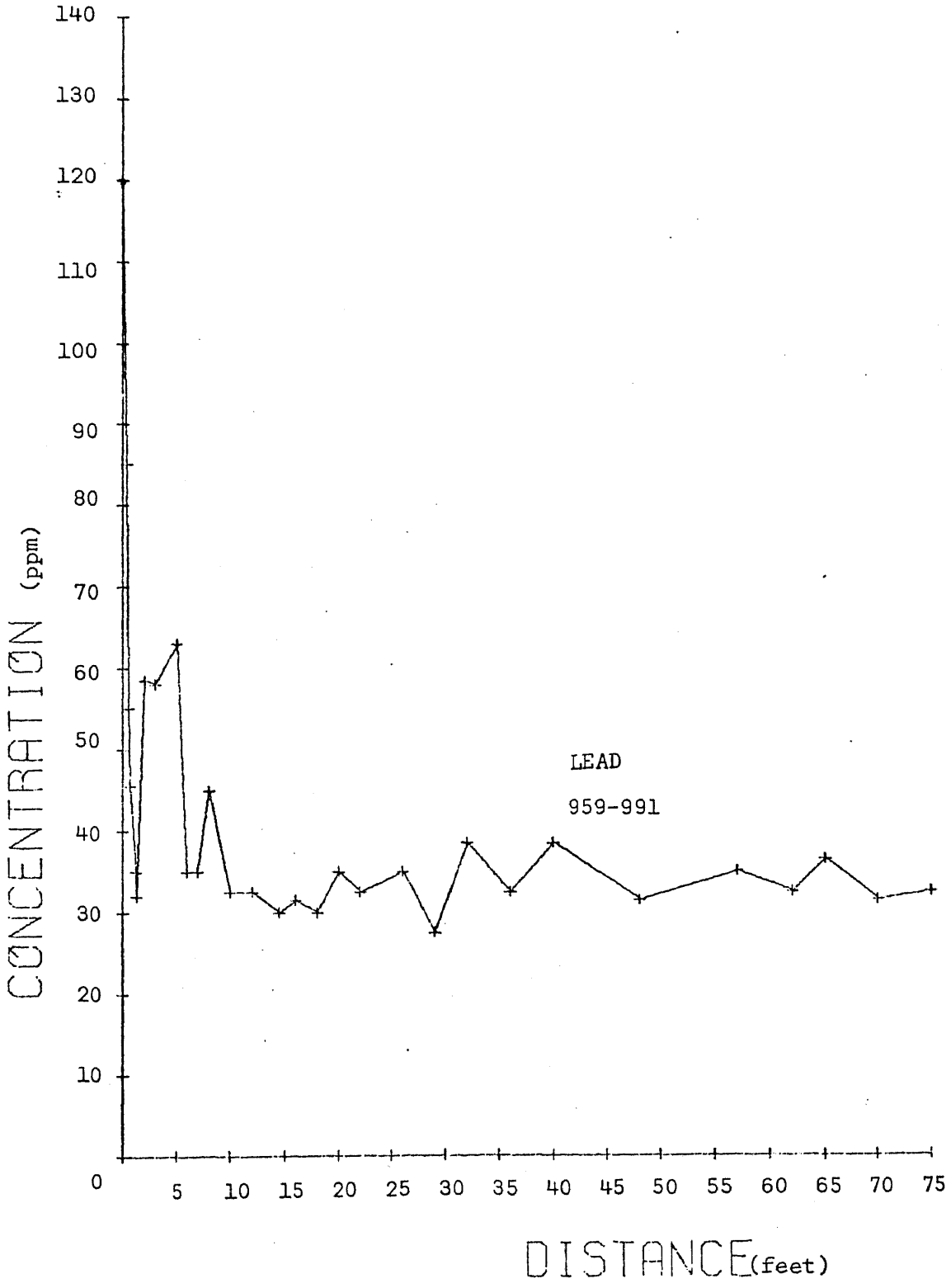

Figure 15. Lead dispersion pattern, Chief of the Hill Mine, Line C.

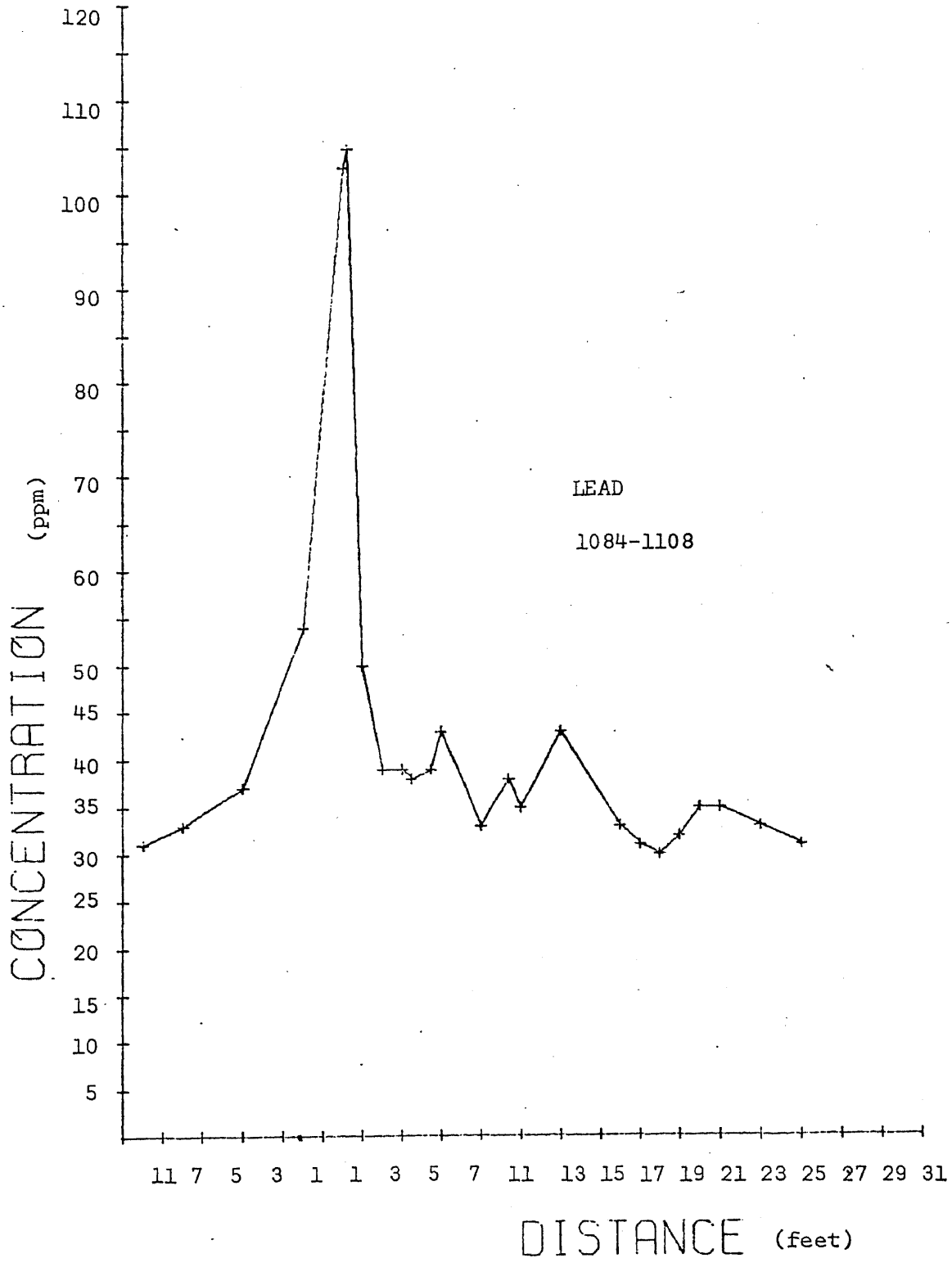

Figure 16. Lead dispersion pattern, Chief of the Hill Mine, Line D.

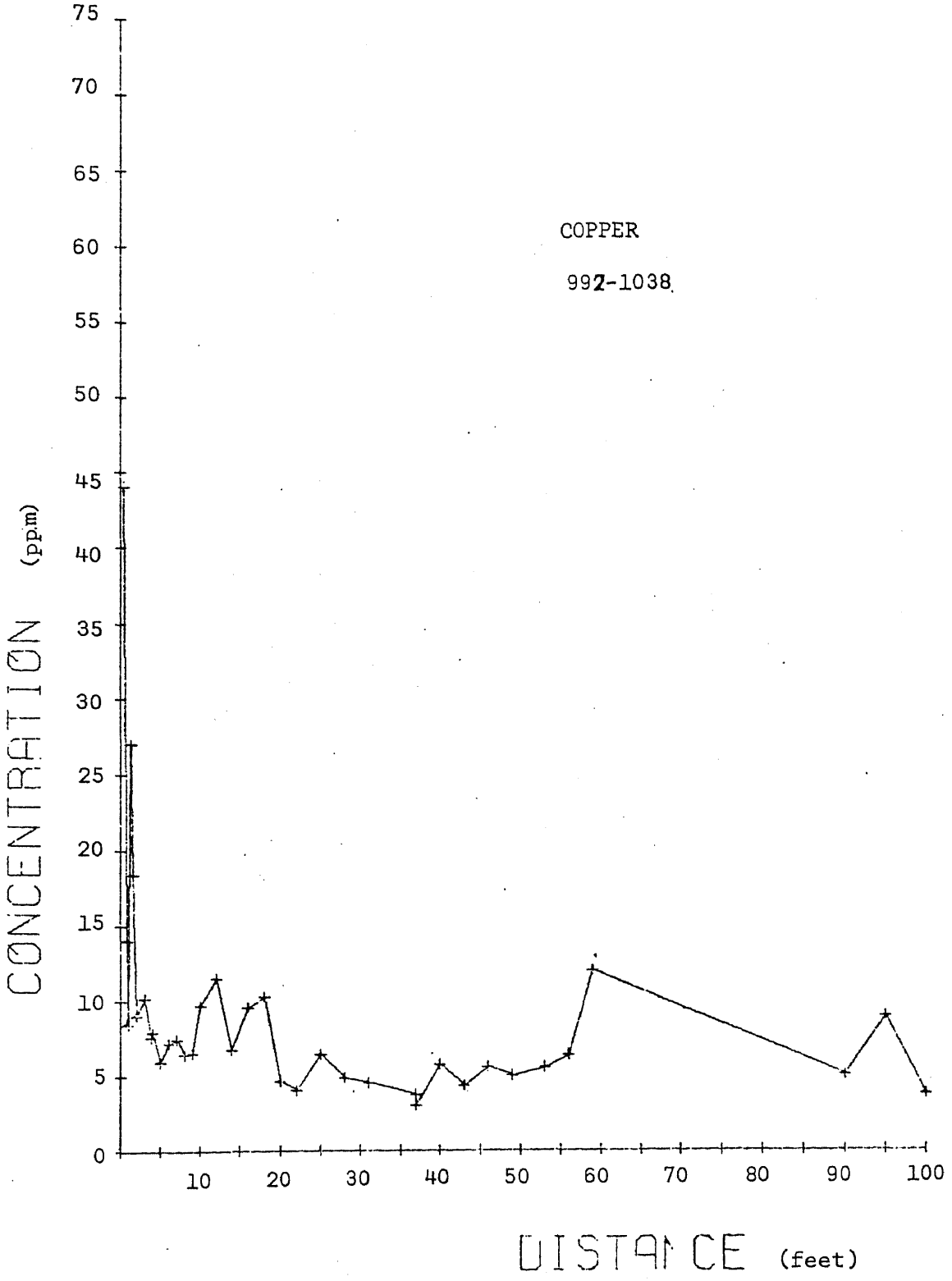

Figure 17. Copper dispersion pattern, Chief of the Hill Mine, Line A.

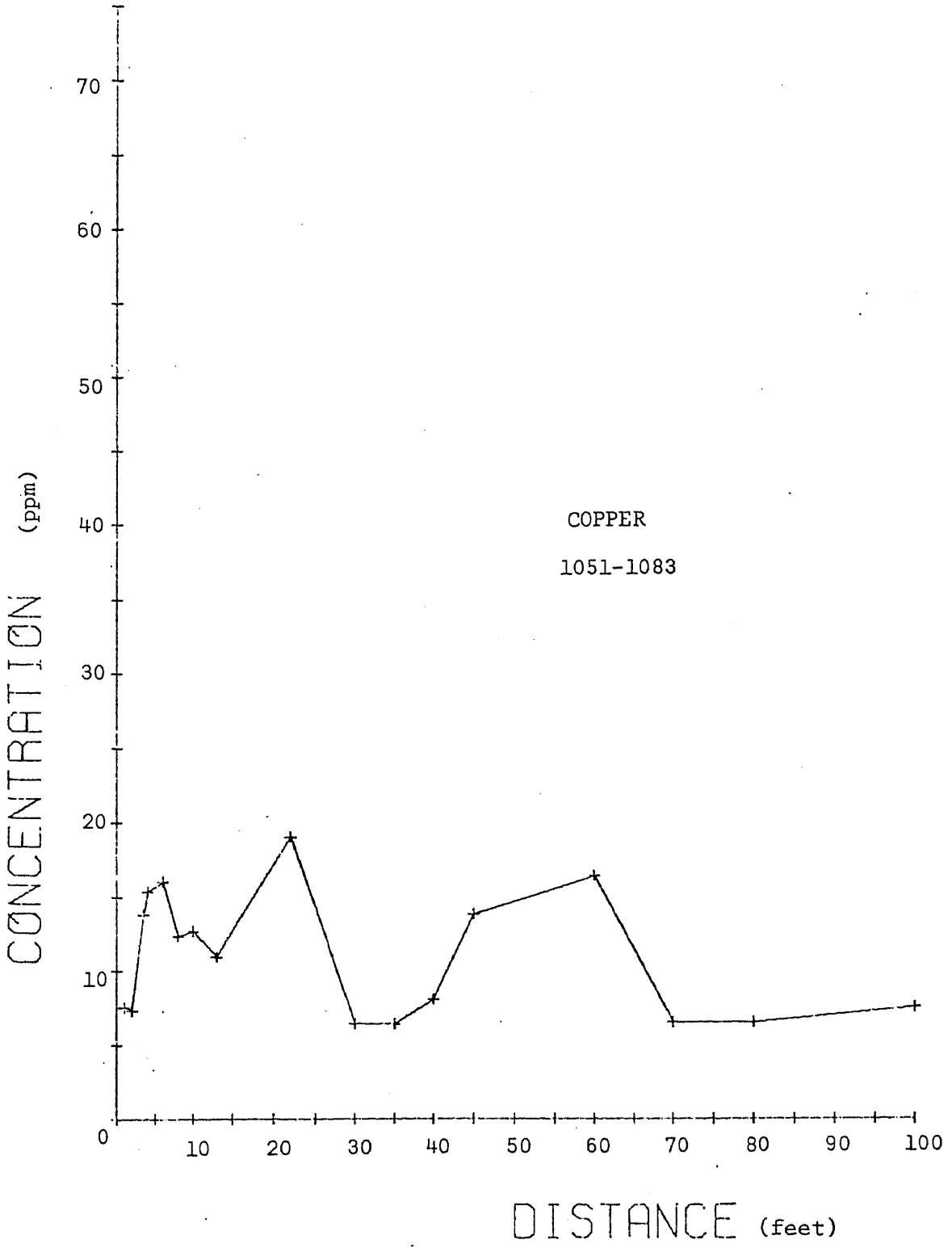

Figure 18. Copper dispersion pattern, Chief of the Hill Mine, Line B.

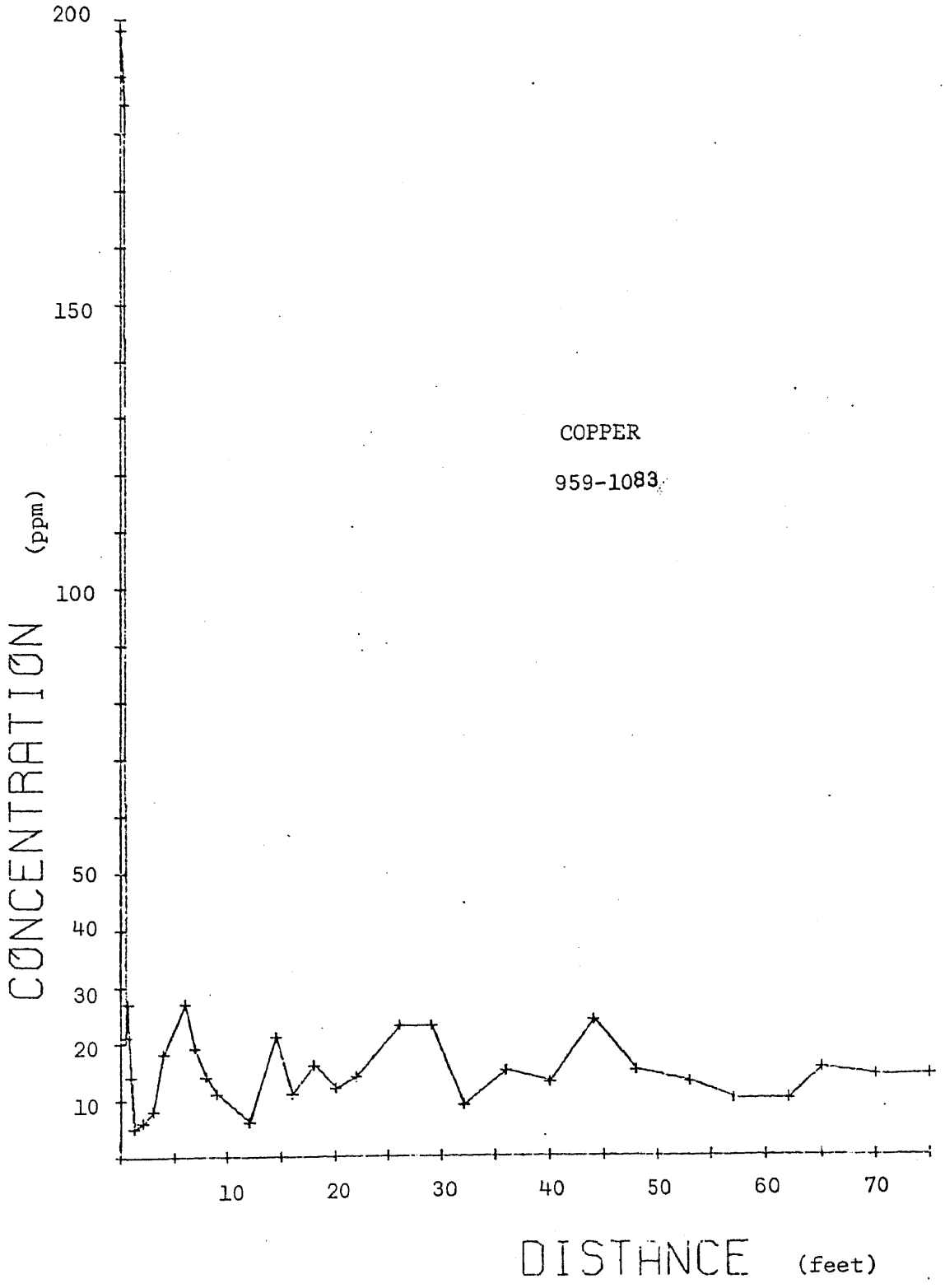

Figure 19. Copper dispersion pattern, Chief of the Hill Mine, Line C.

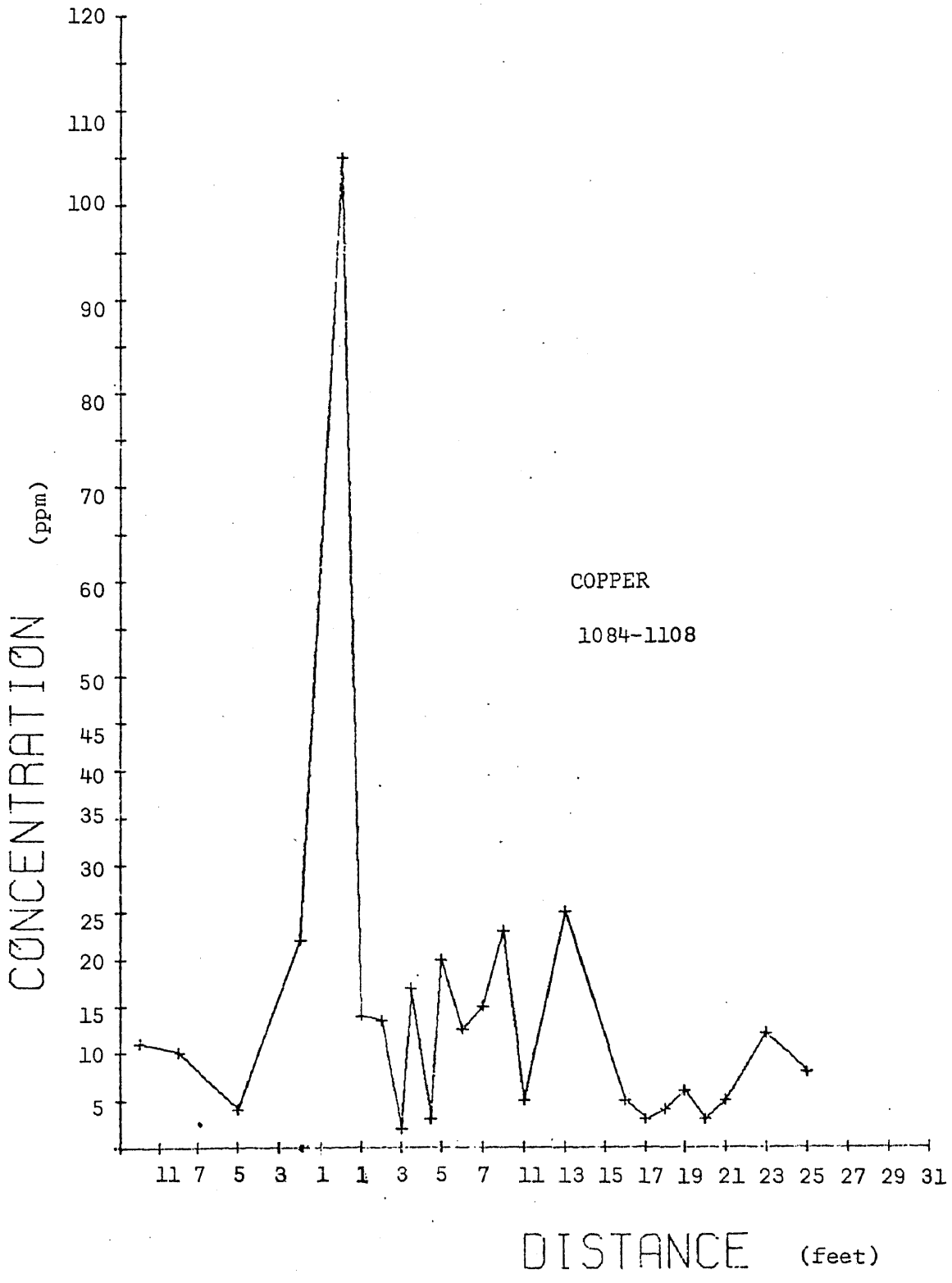

Figure 20. Copper dispersion pattern, Chief of the Hill Mine, Line D.

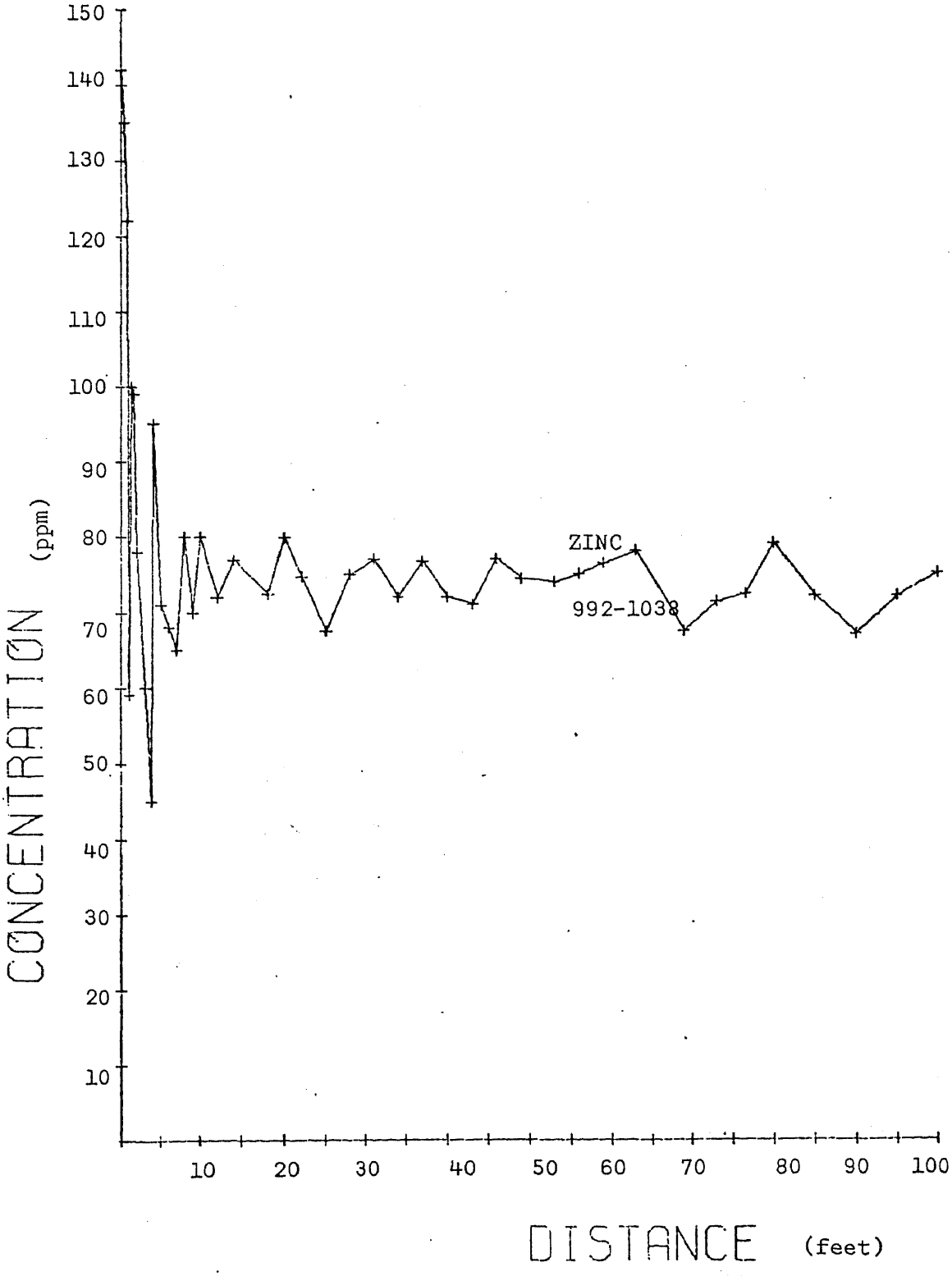

Figure 21. Zinc dispersion pattern, Chief of the Hill Mine, Line A.

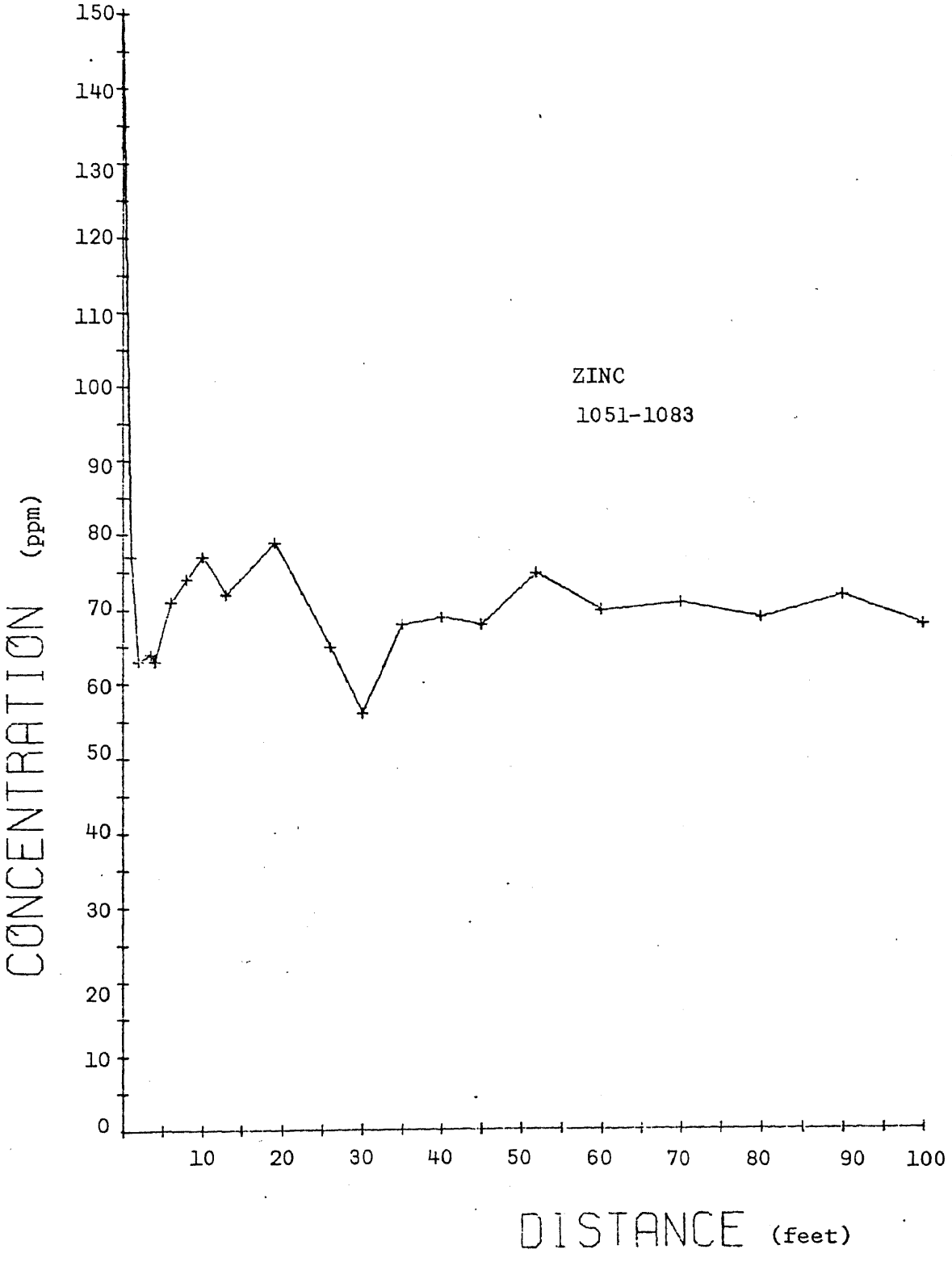

Figure 22. Zinc dispersion pattern, Chief of the Hill Mine, Line B.

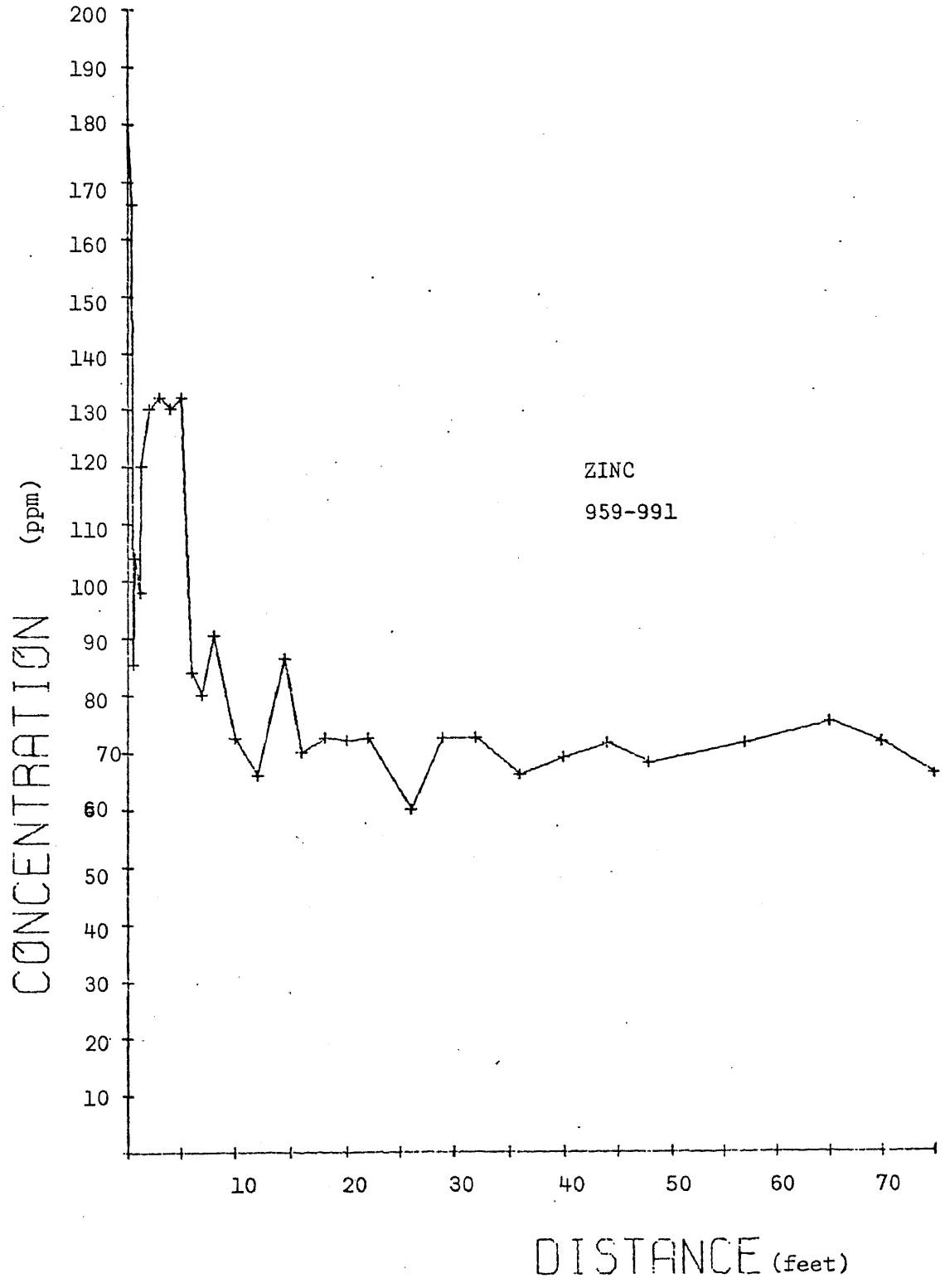

Figure 23. Zinc dispersion pattern, Chief of the Hill Mine, Line C.

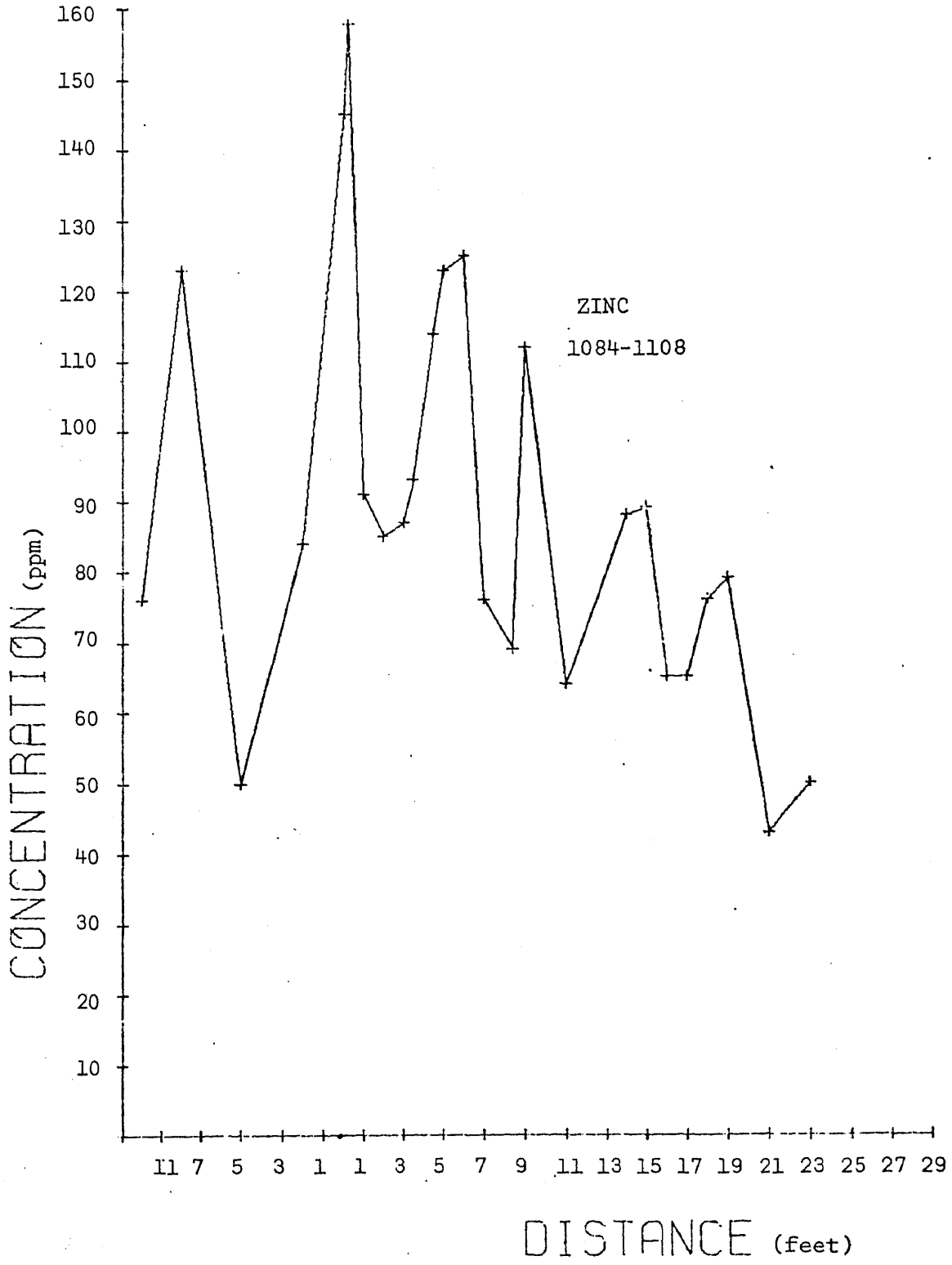

Figure 24. Zinc dispersion pattern, Chief of the Hill Mine, Line D.

a. A sharp decrease of the silver values from 3-2 ppb at 5-6 feet, to 1200-400 ppb at 15-20 feet.

b. A gradual decrease with a smooth slope to the background value, 9-40 ppb at 40-80 feet.

3. Lead, Copper and Zinc Dispersion Patterns

Figures 13 to 16, and Figures 17 to 20, and Figures 21-to 24 show the distribution of lead, copper and zinc respectively along the sampling lines A, B, C and D. The different figures for the lead, copper and zinc do not show any extensive patterns. Tables 1 to 4 list the values of the lead, copper and zinc in the vein and the wall rocks. The results indicate that the vein contains only minimum amounts of these metals of which explains the poorly developed dispersion patterns.

C. Dispersion Patterns of the Trace Elements in the Wall Rock of the Duplex Mine

One hundred and fifty vein and wall rock samples from the fifth and sixth levels of the Duplex Mine were analyzed for gold, silver, lead, copper and zinc. The trace elements concentrations are listed in Tables 5 through 7, Appendix A. Figures 24 to 37 show the distribution of the gold, silver, lead, copper and zinc along the sampling lines E, F, D and G.

1. Gold Dispersion Patterns

Figures 24 and 25 show the distribution of gold in the wall rock of the New Year's Gift and Fraction veins along the

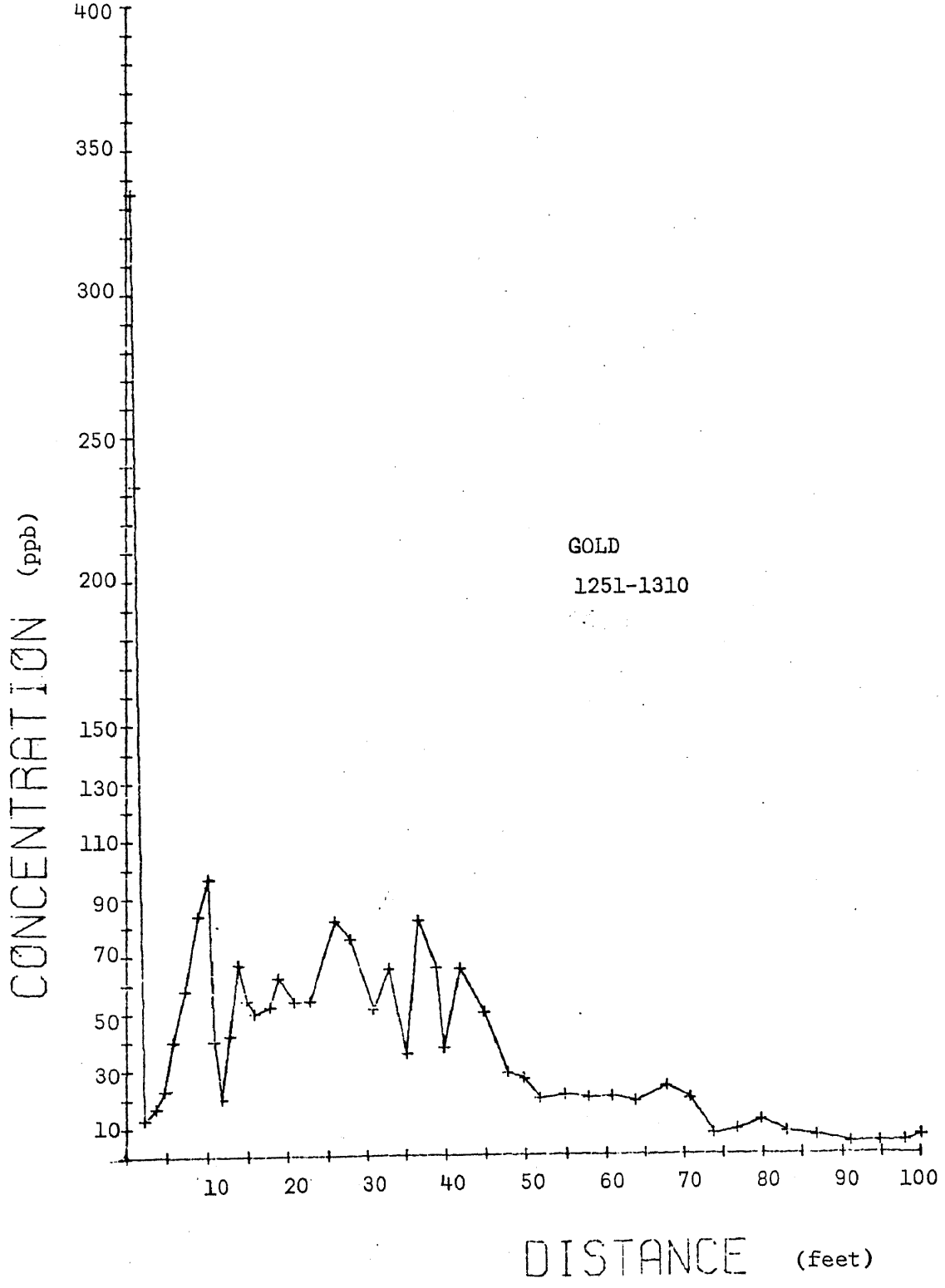

Figure 25. Gold dispersion pattern, 5th level of Duplex Mine, Line E.

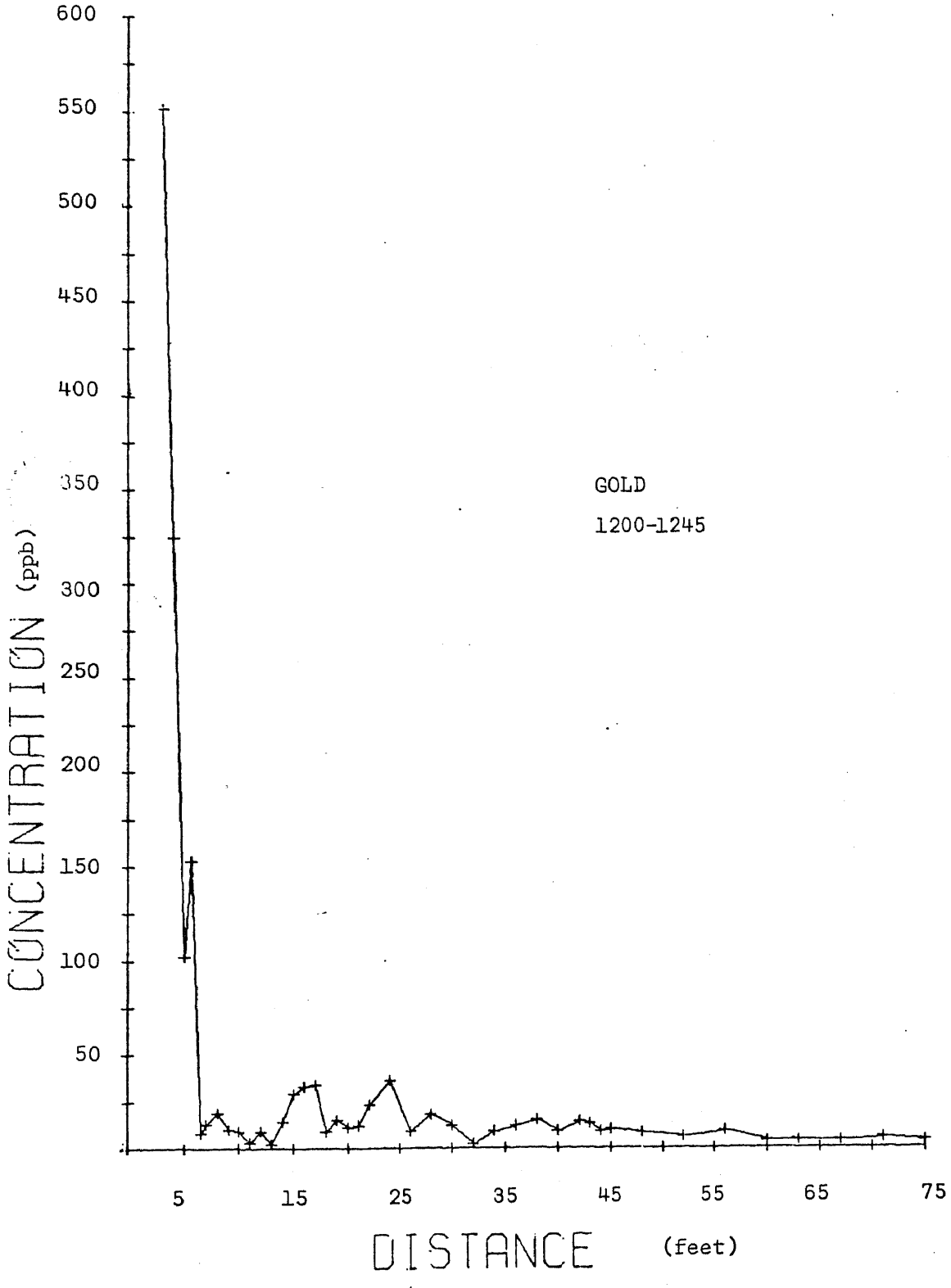

Figure 26. Gold dispersion pattern, 6th level of Duplex mine, Line G.

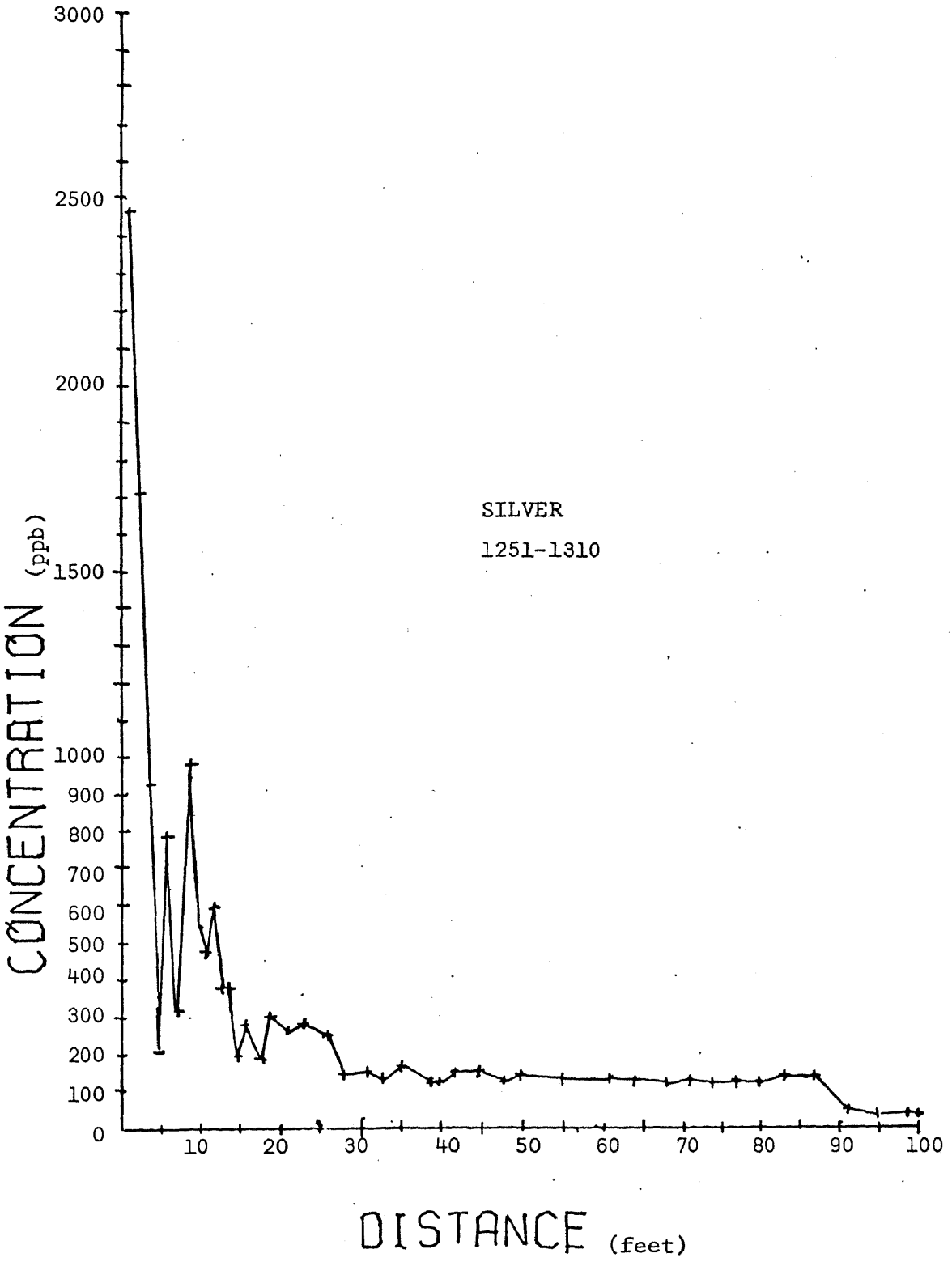

Figure 27. Silver dispersion pattern, 5th level of Duplex mine, Line E.

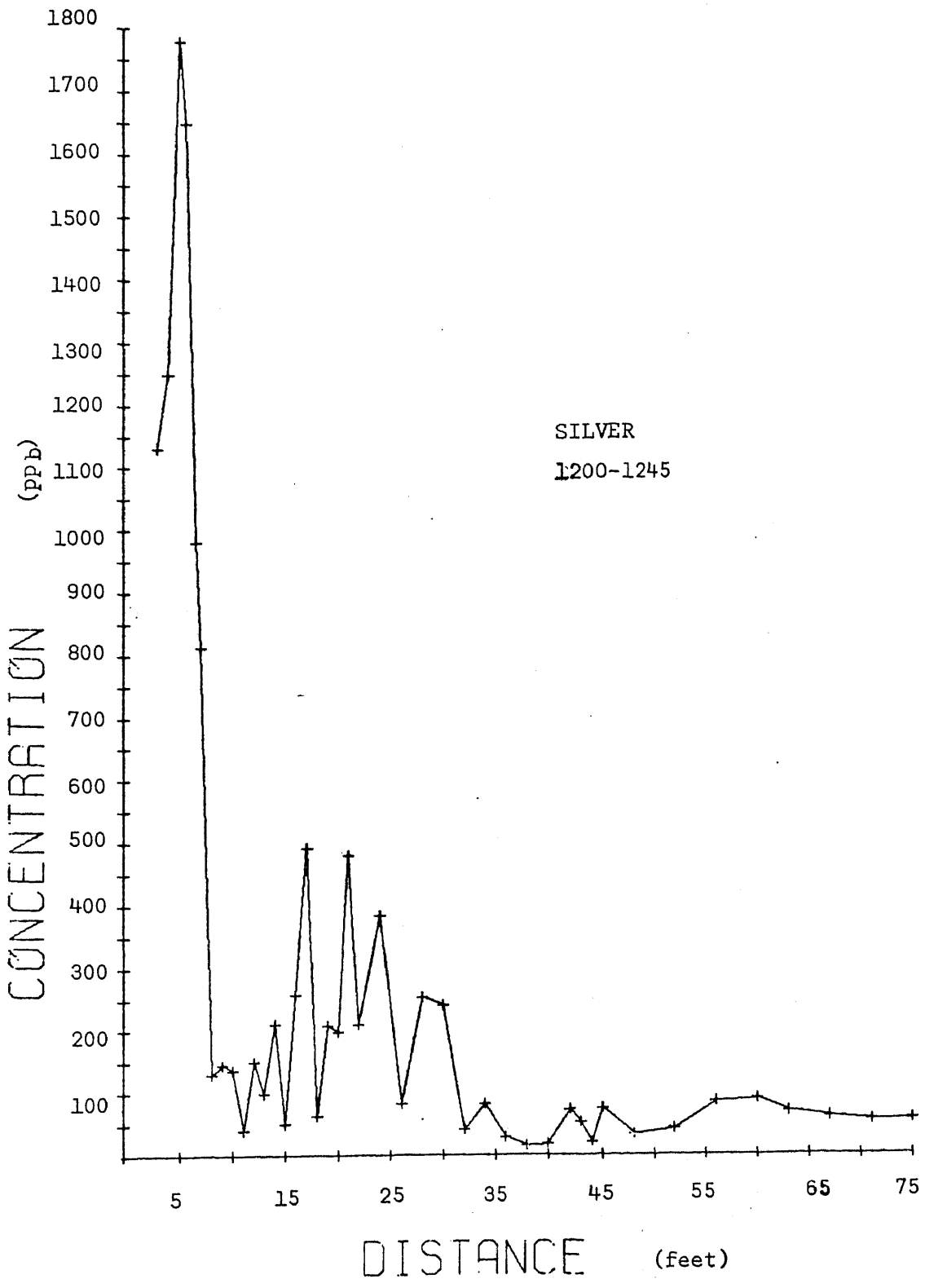

Figure 28: Silver dispersion pattern, 6th level of Duplex mine, Line G

lines E and G. The gold values show an abrupt decrease to 10 ppb at about 5-7 feet from the vein. At distances ranging from 7-40 feet the gold shows erratic distribution with values up to 100 ppb. Then there is a steady decrease in the gold concentration till the background values are reached at about 90 feet. In general, the gold dispersion patterns shown by Figures 24 and 25 resemble those shown by Figures 1 and 4 of the Chief of the Hill Mine.

2. Silver Dispersion Patterns

Figures 26 and 27 show the distribution of the silver along the sampling lines E and G. The dispersion pattern of silver can be divided into two parts,

a. Abrupt decrease of silver values to the range 200-900 ppb at 5-10 feet from the vein.

b. Gradual decrease of silver values from 5-10 feet to 40-80 feet from the vein until it reaches the background of 90-40 ppb.

The dispersion patterns of the silver in the wall rock of the veins in the Duplex Mine resembles those of the Chief of the Hill Mine. This suggests that the migration of silver in the wall rock of the veins throughout the Searchlight District is somewhat similar, and that the dispersion patterns have almost the same trend.

3. Lead, Copper and Zinc Dispersion Patterns

Figures 28 to 33 show the distribution of lead, copper and zinc along the sampling lines E and F, and Figures 34 to 36

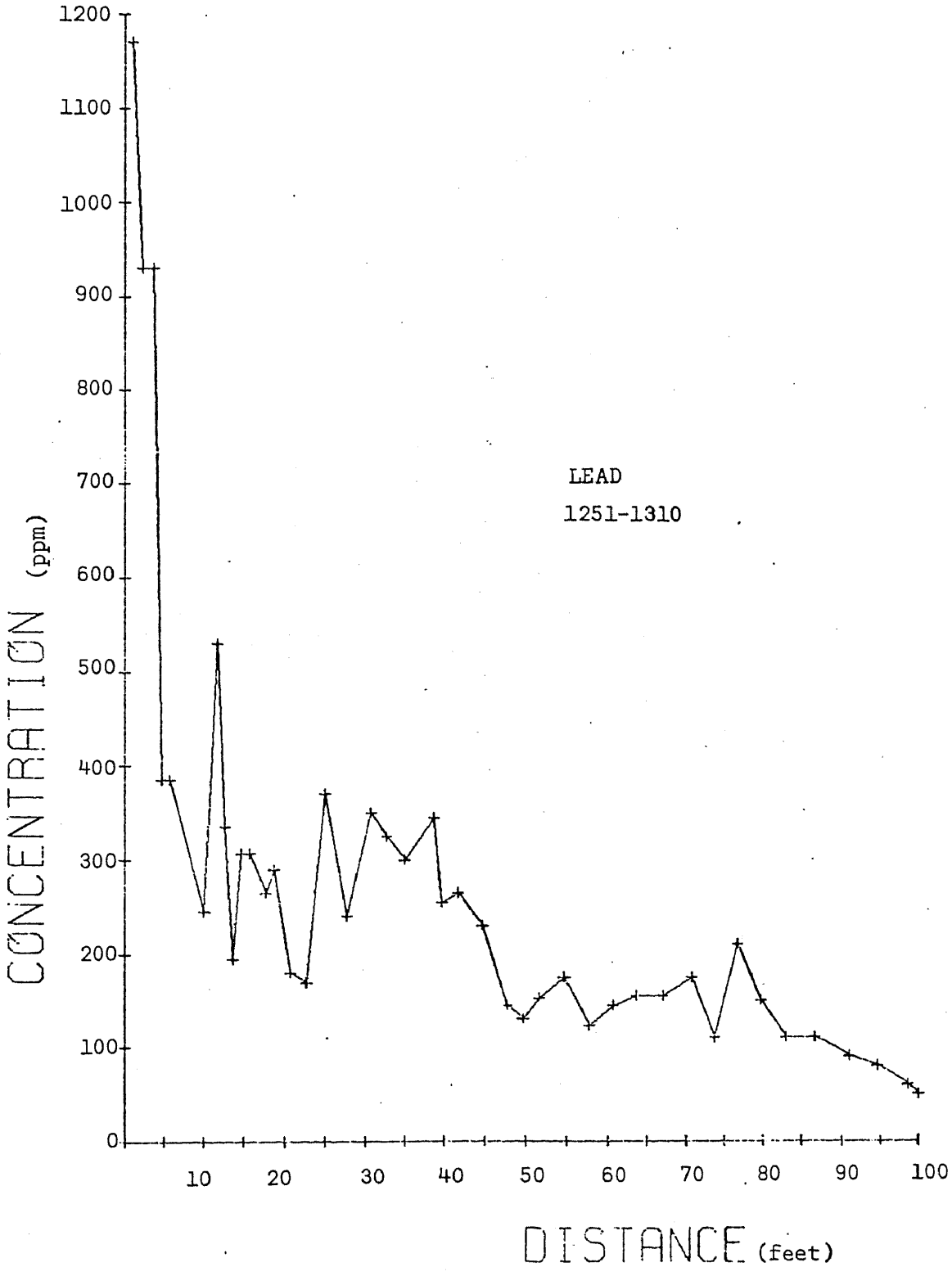

Figure 29. Lead dispersion pattern, 5th level of Duplex mine, Line E.

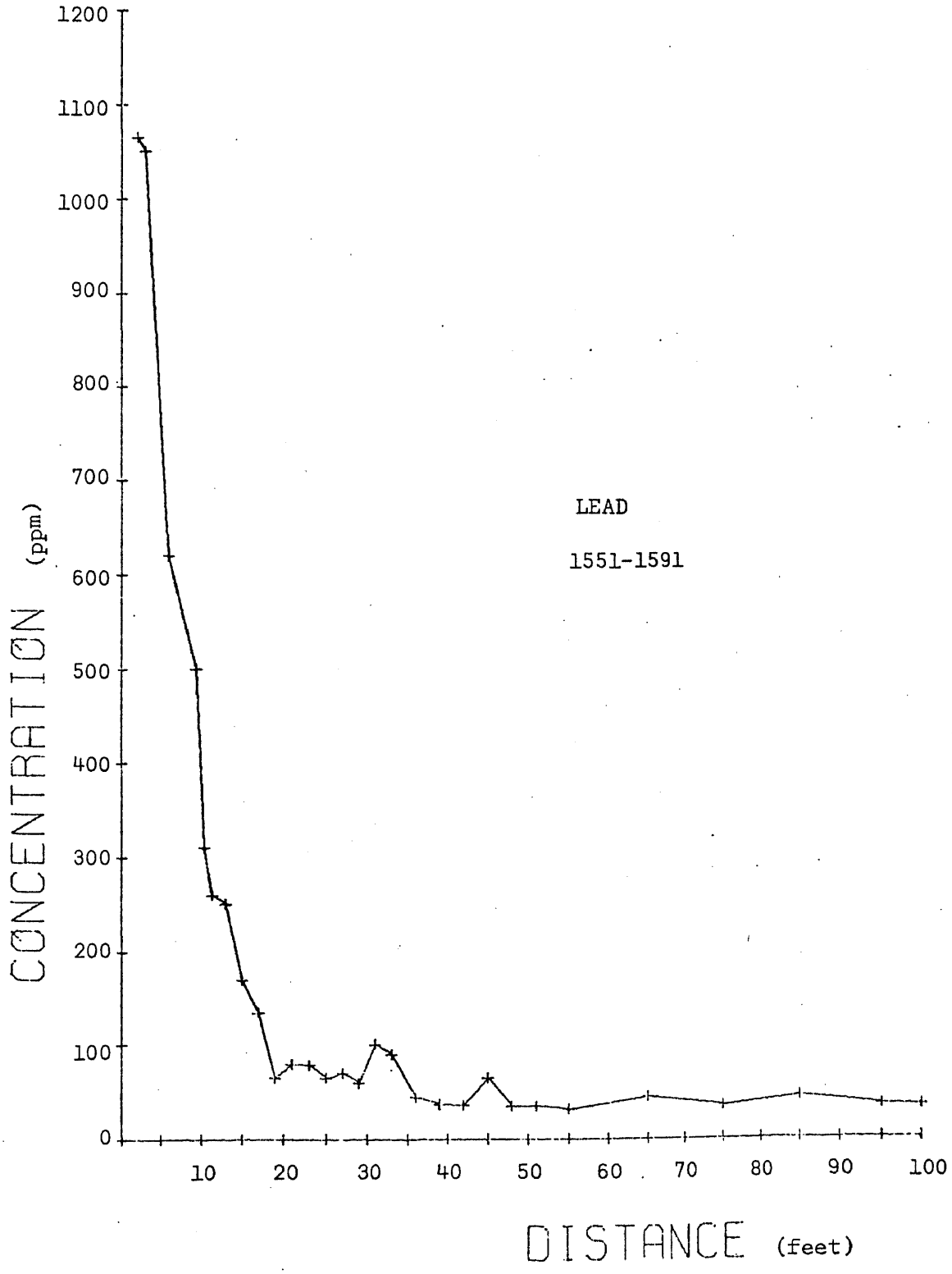

Figure 30. Lead dispersion pattern, 5th level of Duplex mine, Line F.

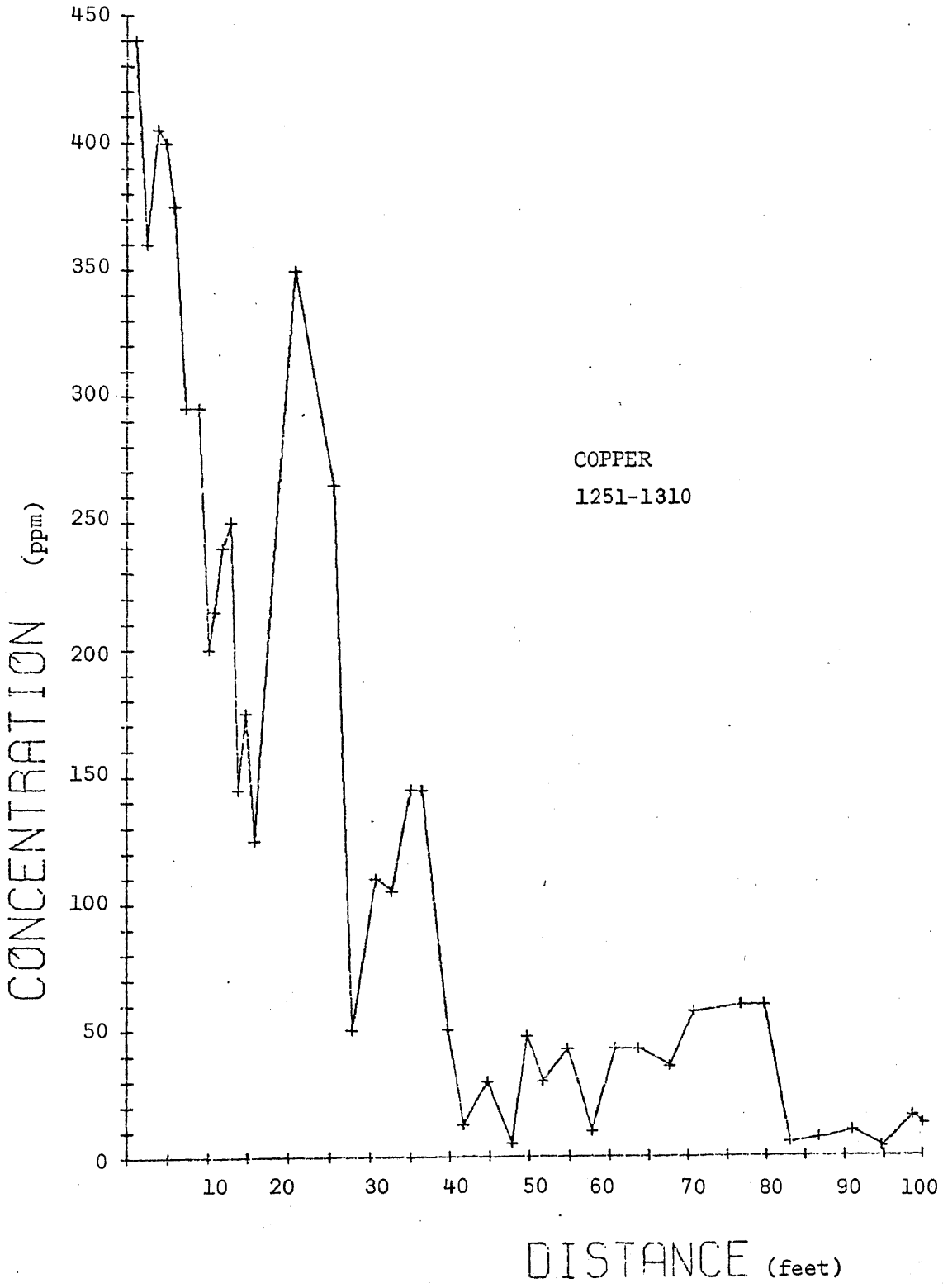

Figure 31. Copper dispersion pattern, 5th level of Duplex mine, Line E.

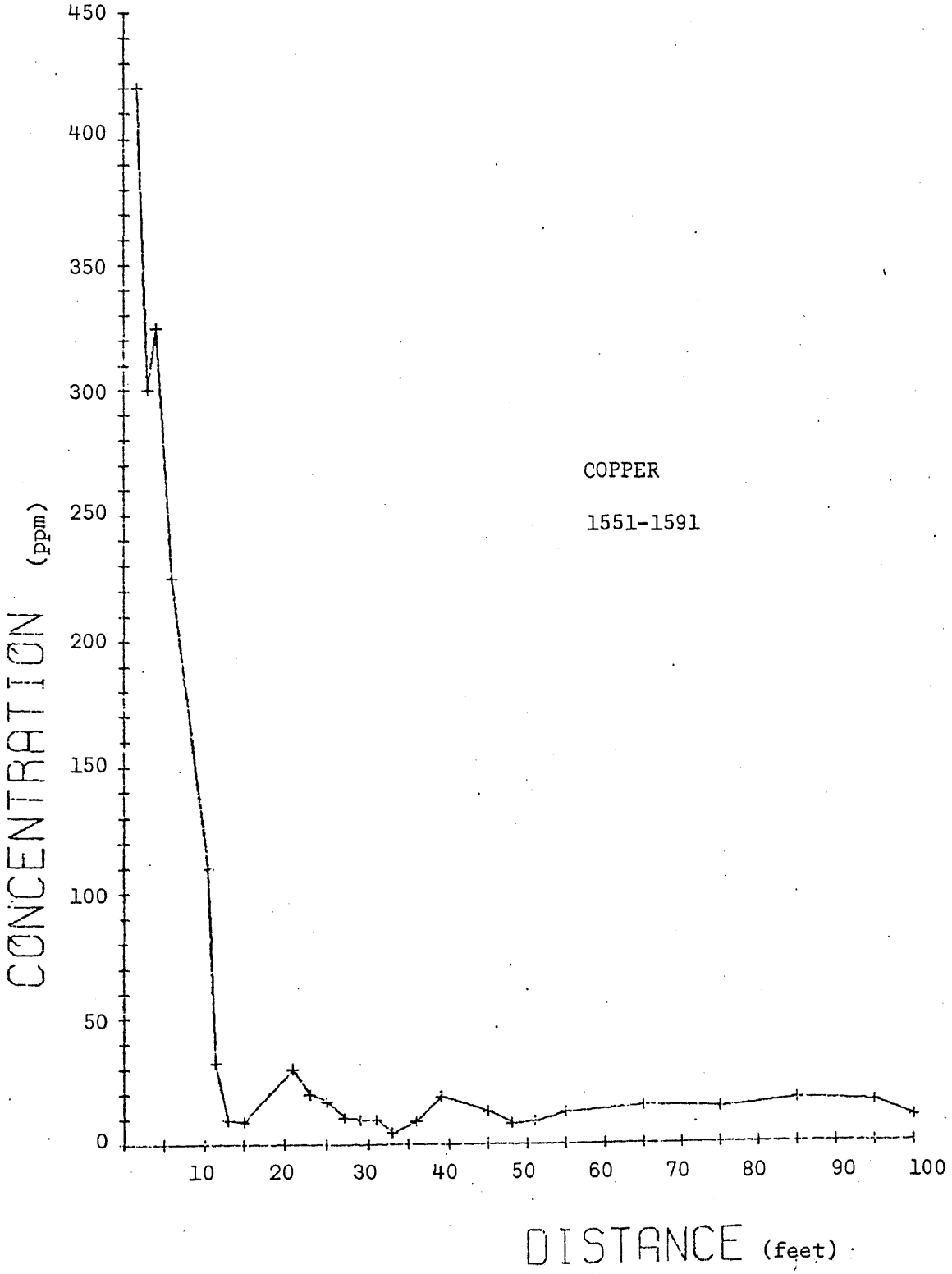

Figure 32. Copper dispersion pattern, 5th level of Duplex mine, Line F.

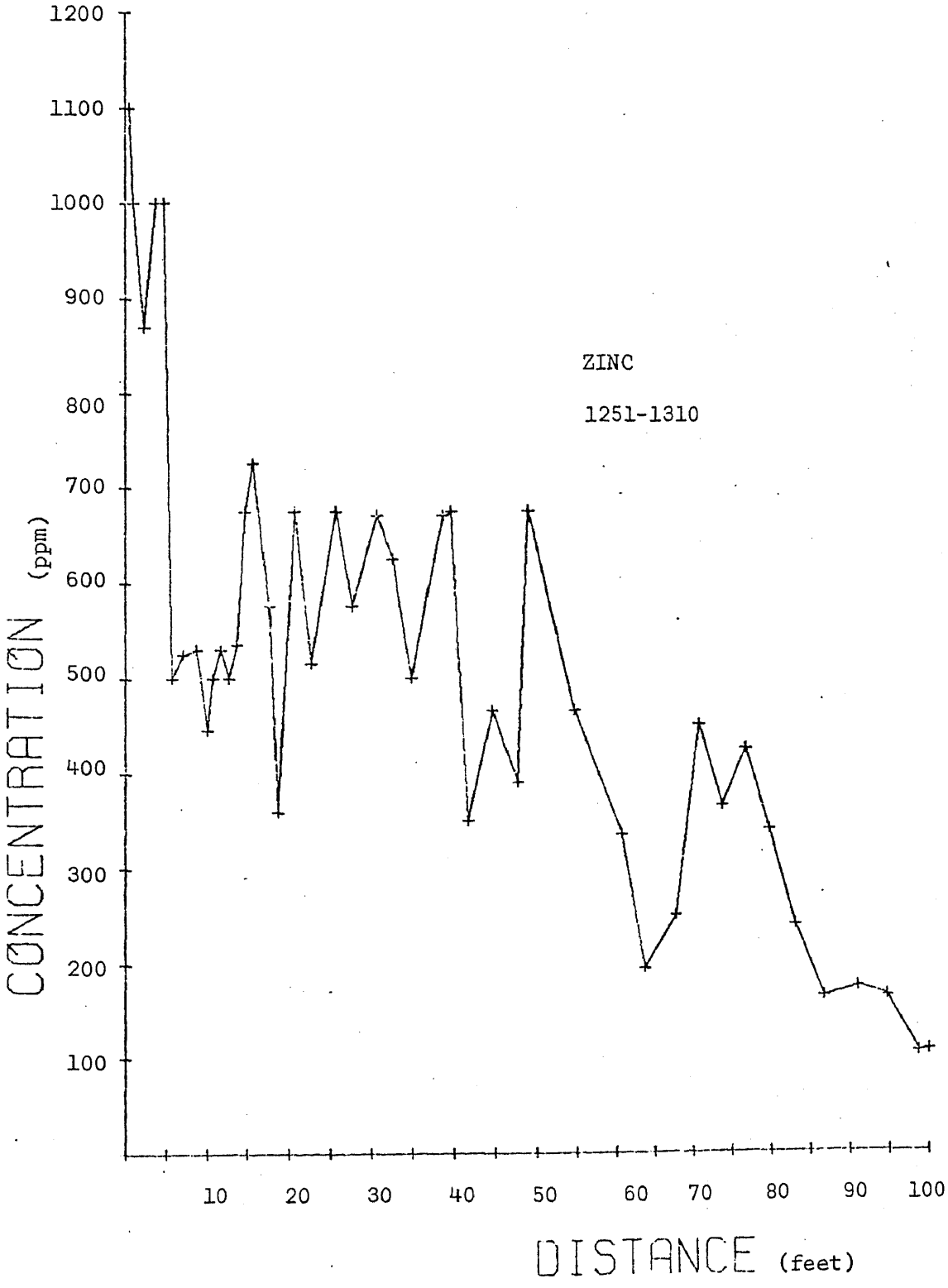

Figure 33. Zinc dispersion pattern, 5th level Duplex mine, Line E.

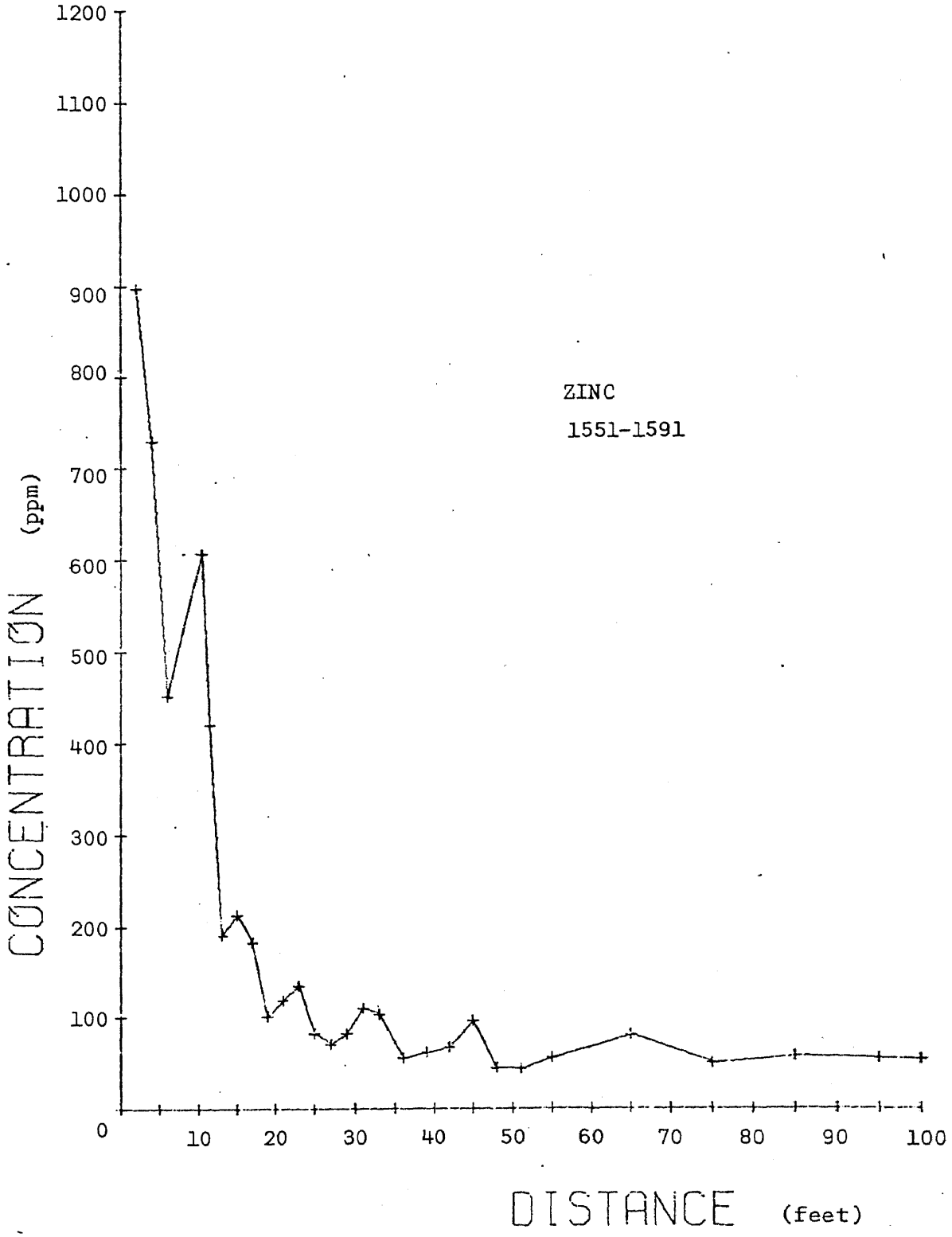

Figure 34. Zinc dispersion pattern, 5th level of the Duplex mine, Line F.

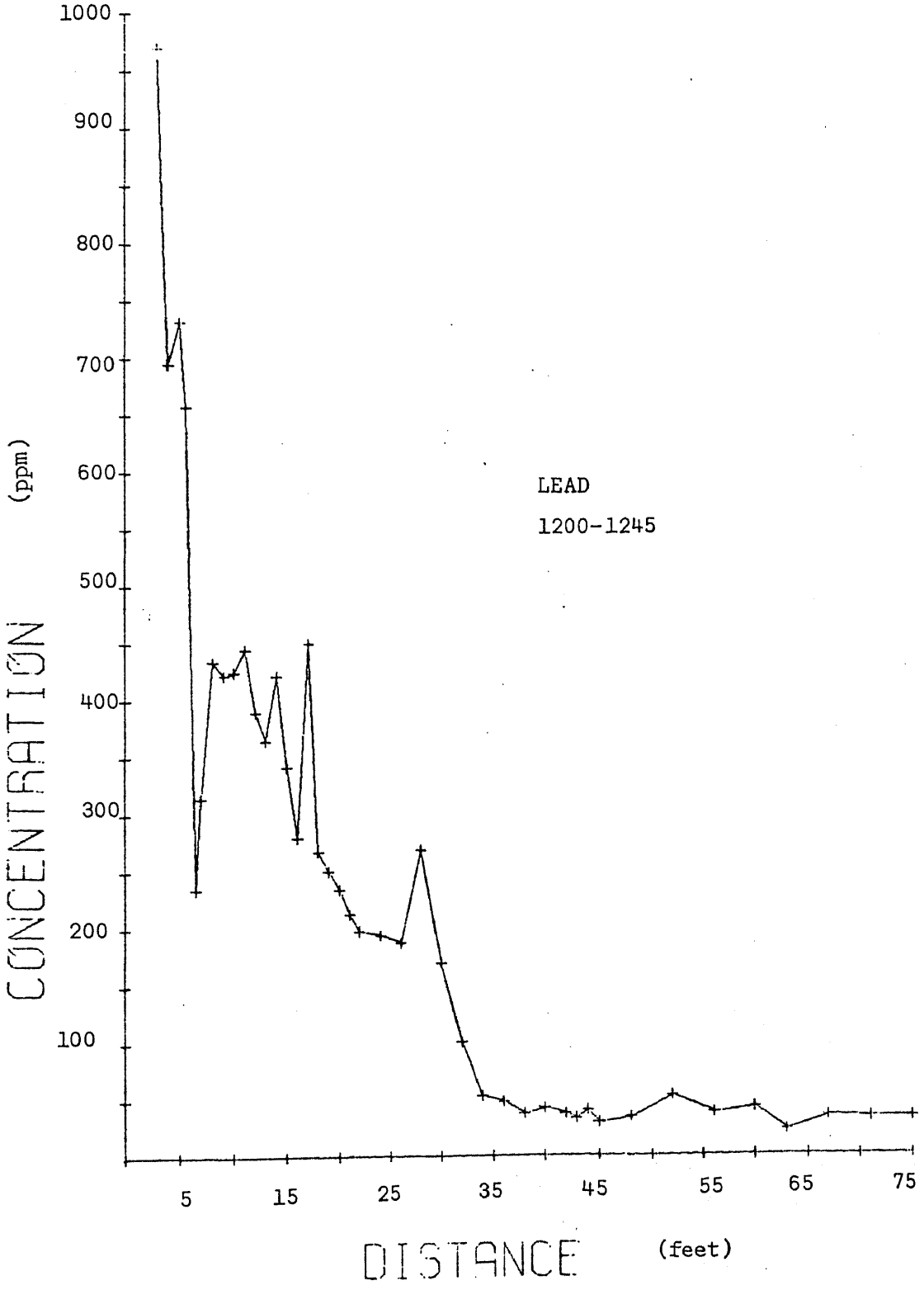

Figure 35. Lead dispersion pattern, 6th level of Duplex mine, Line G.

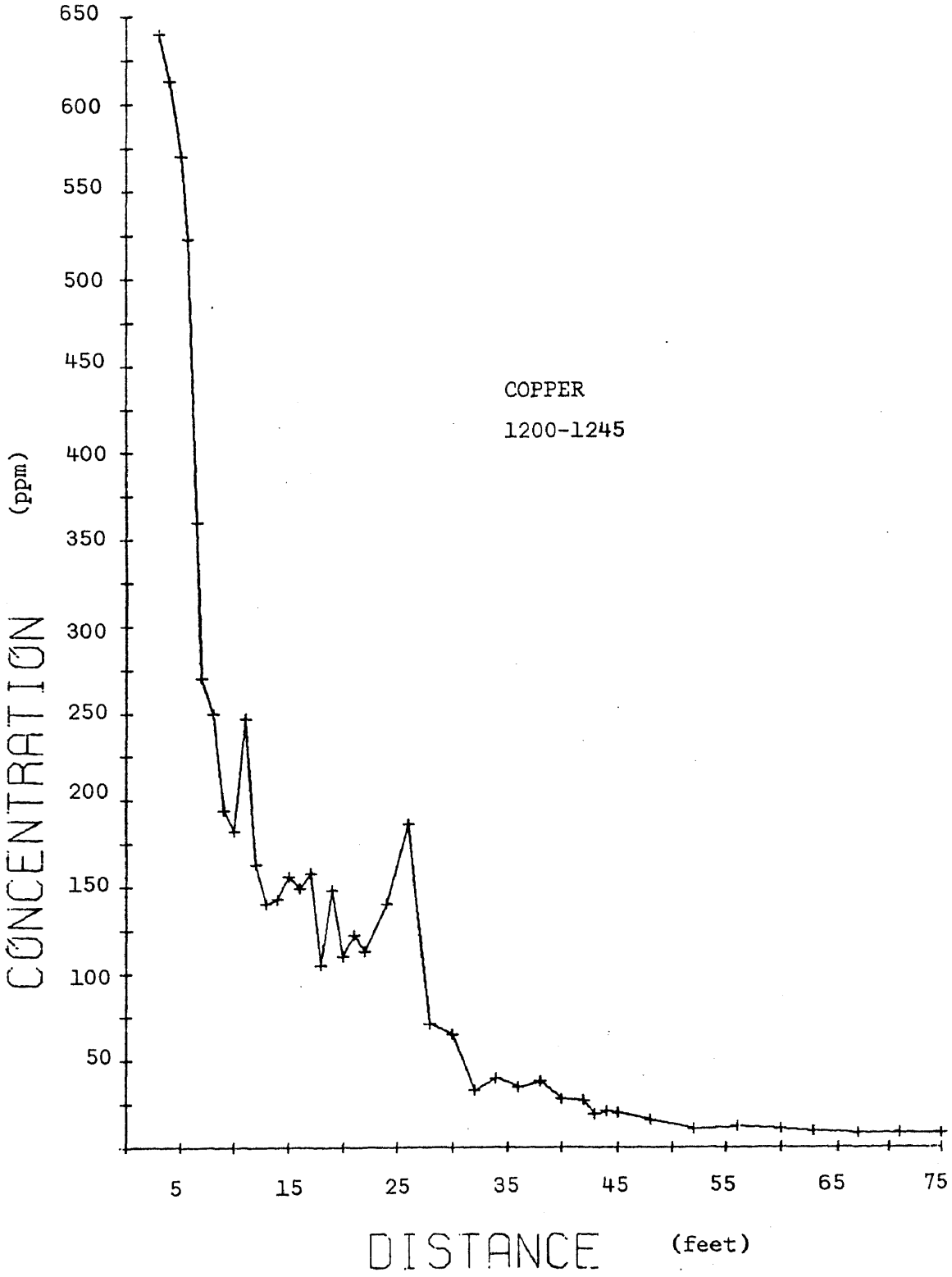

Figure 36. Copper dispersion pattern, 6th level of Duplex mine, Line G.

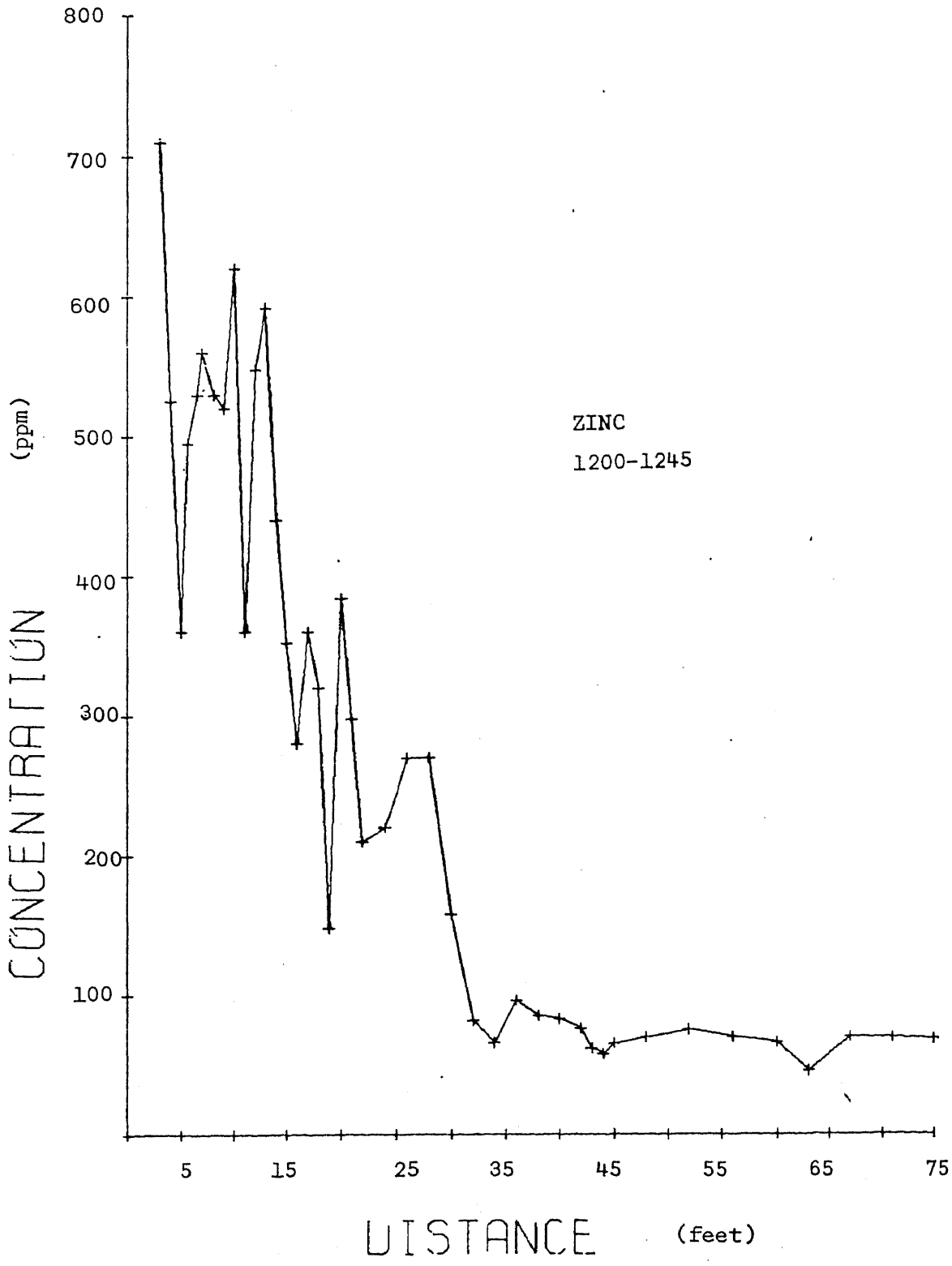

Figure 37. Zinc dispersion pattern, 6th level of Duplex mine, Line G.

show the distribution along the line G.

It has been suggested that the depth of penetration of the trace elements in the wall rock is a function of many variables. Here it is important to emphasize the effect of the concentration of the trace elements in the hydrothermal solution on the dispersion patterns in the wall rock.

Comparing the dispersion patterns of lead, copper and zinc in the wall rock of the Chief of the Hill vein (Figures 13 to 24), with the dispersion patterns of the same elements in the wall rock of the veins of the Duplex Mine (Figures 29 to 33), it is noted that the penetration of the trace elements in the wall is deeper (60-100 feet) at the Duplex vein than that of the Chief of the Hill vein (2-5 feet). The Duplex Mine dispersion patterns of lead, copper and zinc are well developed and they show gradual decrease from the veins in contrast to those of the Chief of the Hill, which do not show any extensive patterns. Hence the size and the extension of the anomaly in the wall rock is affected strongly by the concentration of the traee elements in the vein itself.

An interesting factor is demonstrated through the dispersion patterns along the lines E and F. The vein is displaced by faulting, as shown in Figure 38. Line E represents the hanging wall and line F the foot wall of the same vein. The extension of the anomalies in the hanging wall is much greater than in the foot wall.

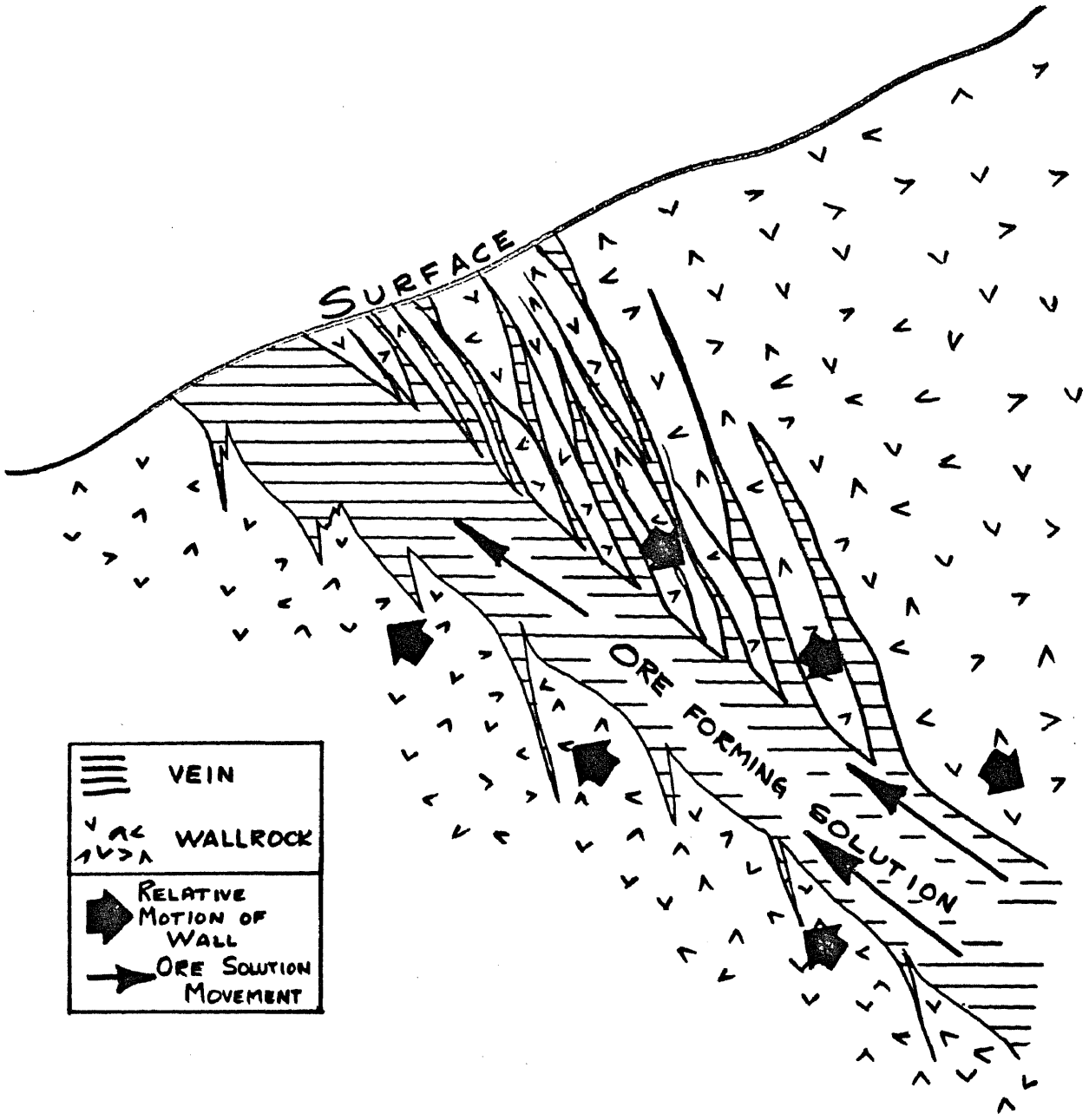

Figure 38. Diagram of footwall-hanging wall relationship with ore-forming solution.

This would suggest that the rising ore-forming solution will fill the fractures in the hanging wall more easily and thus increase the area in contact with ore-forming solution in the hanging wall compared to the foot wall. Thus the penetration of the ore-forming solution in the hanging wall will be greater than that in the foot wall.

D. Selenium, Arsenic and Molybdenum Distribution in the Veins and Wall Rock

Six samples were analyzed for selenium by neturon activation analysis. Selenium in the veins and the wall rocks of the Searchlight District does not show much variation and the vein concentrations are similar to the background values, obtained from the analysis of igneous and volcanic rocks, which is around 0.7 ppm. Arsenic was not detected by atomic absorption spectrophotometry. Molybdenum results averaged about 8 ppm and did not show significant variation between the veins and the wall rocks.

E. Statistical Evaluation of the Data

Regression methods were used to describe the degree and the form of the association between variables. The regression analysis was carried out using modified subroutine computer programs obtained from the "System 360 scientific subroutine pack (360 A-CM-03X) version III, Program Manual". Two regression techniques were used and are described below.

1. Linear Regression Correlation

According to Strahlor (1954),

> Correlation is a means of determining the degree of linear mathematical association between two variables without regard to the physical function that relates them.

The linear regression correlation was chosen as the statistical method to establish the effect of one independent variable on a dependent variable. The X and Y variables represent the concentration of the different trace elements studied.

The general linear relation between the mean value of the dependent Y and independent variable X, is expressed

$$Y = bo + b_1 x_1$$

while

bo is a constant

b_1 is the regression coefficient.

The significance of regression coefficient and the regression equation is tested by using t-test and F=test respectively.

a. t-Test

In testing the significance of the regression coefficients, we apply the t-test which is equal to

$$t = b_1 / S_{b_1}$$

where b_1 is the regression coefficient

S_{b_1} is the standard deviation of the regression coefficient.

If the calculated t value exceeds the critical value given by the appropriate tables with v=n-k-1., degree of freedom, then the regression coefficient is significant and the null hypothesis Ho:b_1=0 is rejected. The 95th percentile level was chosen as the desired level to accept or reject data (Krumbine, 1965).

b. F-test

F is a ratio of the variance contributed by the regression and the error variance. This determines whether the regression equation used is significant or not. It is calculated as follows:

$$F = \frac{\text{sum of squares attributed to the regression/K}}{\text{sum of squares of deviation from the regression/(n-k-1)}}$$

If calculated F value with v_1=k and v_2=n-k-1 degrees of freedom is greater than the value from the F-table corresponding to the desired level of significance, then the regression equation is significant and the common regression line x adequately represents the data. The 95th percentile level was chosen as the desired level to accept or reject data (Krumbine, 1965).

c. Correlation Coefficient

According to Griffith (1951) "If x and y are two variables to be compared, the degree of similarity between the two can be addressed by a correlation coefficient y." This coefficient is defined as

$$r^2 = 1 - \frac{\sigma^2_{xy}}{\sigma_y^2} = 1 - \frac{\Sigma(y_o - y_c)^2}{\Sigma(y_o - \bar{y})^2}$$

$$r = \sqrt{r^2}$$

σ^2_{xy} is the variance of y around the regression line

σ_y is standard deviation of y

yo is the observed value of y

y_c is the calculated yo for a given value of x_i

$\bar{y}$ is the mean

This coefficient ranges from +1 to -1. The correlation coefficient approaches unity as the degree of association between the variables increases.

The table below shows the correlation between both silver and gold with lead, copper and zinc for the samples (1251, 1921) taken along line E of the Duplex Mine.

Table 9. T-test, F-test, and the correlation between silver and gold with lead, copper and zinc, Line E.

Independent Variable	Dependent Variable	t-test Reg. Coff.	F-test Reg. Eq.	Correlation	
Ag	Cu	sig.	sig.	.8095	sig.
Ag	Pb	"	"	.7975	"
Ag	Zn	"	"	.5086	"
Au	Ag	non	non	.2814	non
Au	Cu	"	"	.3538	"
Au	Pb	"	"	.2136	"
Au	Zn	"	"	.2358	

The data listed in this table shows that the silver is highly positively correlated with copper and lead and roughly correlated with zinc. On the other hand, gold shows no significant correlation with the other metals.

2. Nonlinear Regression "Logarithmic Transformation"

Lovering and Morris (1952) suggested that copper, lead and zinc content of the wall rock decreases logarithmically with the distance. To evaluate this suggestion, a nonlinear regression with logarithmic transformation was used. In a logarithmic transition of data the relation between the x and y variables is expressed as:

$$y = \alpha \beta^{-x}$$

$$\text{Log } y = \log \alpha - x \log B$$

where

is the intercept

Table below lists the values of the correlation coefficient and the square of the correlation coefficient which can be stated as the precent of the variation which is common to both variables.

Table 10. The correlation between the distance outward from the vein and the concentration of lead, copper, zinc, silver and gold.

Independent Variables	Dependent Variable	Correlation r	100 r^2
Dist.	Lead	.8688	75.43
Dist.	Copper	.85054	73.92
Dist.	Zinc	.8489	70.86
Dist.	Silver	.83518	69.73
Dist.	Gold	.7853	61.66

The results listed in this table suggest that 75, 73, 70, 69 and 61 percent of the variation of lead, copper, zinc, silver and gold is common to both variables (concentration and distance), whereas 25, 27, 30, 31 and 39 percent unexplained in the association.

VI. SUMMARY AND CONCLUSIONS

The intensity and the extension of the trace element anomalies in the igneous wall rock of hydrothermal veins are functions of many variables such as the composition, the temperature and the pressure of the ore-forming solution, the composition and condition of the wall rocks, etc.

The concentration of the trace elements in the ore-forming solution is an important factor in determining the shape and extension of the anomaly in the wall rock. This was shown clearly by the well developed dispersion patterns of lead, copper and zinc in the wall rock of the veins in the Duplex Mine in contrast to those of the Chief of the Hill vein.

The orientation of the fractures which fanned out from the area of major strain at the Duplex Mine fault is another factor which determines the shape and the extension of the amonaly. This is shown by studying relationships between the hanging wall and the foot wall of the 5th level Duplex Mine. The intensity and the extension of the anomaly is more pronounced in the hanging wall. That indicates that the rising ore-forming solution moved along the fault and then spread into the hanging wall fractures which are more readily accessible than those of the foot wall.

In studying the correlation between the different trace elements, it is found that silver positively correlated with copper and lead and with zinc to a certain extent. Gold does not show any significant correlation. The reason for this may be due to

an erratic distribution of gold in the wall rock. The degree of fit of the actual values of the concentration of the trace elements to the logarithmic curve predicted by Lovering and Morris differs for each element. Copper shows the best fit followed by lead, silver and zinc. The fit of gold was poor.

Thus the statement by Lovering and Morris (1952) that wall rock anomalies are mainly caused by diffusion of the metals, resulting in a logarithmic curve, is not supported by most of the data. It is suggested that in addition to diffusion, other factors also strongly influence penetration of trace elements into wall rocks.

BIBLIOGRAPHY

Banks, C. B., Jr. (1967) Partial analysis of silicate rocks by atomic absorption: Analytical Chemistry, vol. 39, pp. 676-678.

Brunfelt, A.O. and Steinnes, E. (1967), Determination of selenium in standard rocks by neutron activation analysis: Geochemica et Cosmochemica Acta, vol. 31, pp. 283-285.

Callaghan, E. (1939) Geology of Searchlight District, Clark County, Nevada: U.S.G.S. Bull. 906-D, pp. 135-185.

Cornwall, H.R., Lakin, D.M., Nakagawa, A.M. and Stager, H. K. (1967), Silver and mercury geochemical anomalies in the Comstock, Tonoph, and Silver Reef Districts, Nevada, Utah: U.S.G.S. Prof. Paper 575-B, pp. B10-B20.

Crouthamel, C.E. (1960) Applied gamma-ray spectrometery: New York, Oxford, London, Paris, Pergammon Press, pp. 110-134.

Drewes, H. (1967), A geochemical anomaly of base metal and silver in the southern Santa Rita Mountains, Santa Cruz County, Arizona: U.S.G.S. Prof. Paper 575-D, pp. D126-D182.

Finlayson, A.M. (1910) Problems of ore deposition in the lead and zinc veins of Great Britain: Geol. Soc. London Quart. Jour., vol. LXVI, pp. 229-328.

Fitzgerald, F. (1969) Geology of Searchlight District, Nevada: Personal communication.

Ginzburg, I.I. (1960), Principles of geochemical prospecting: Translated from Russian, 311 p.

Goldberg, E.D. and Brown, H.S. (1950), Radiometric determination of gold and rherium: Anal. Chem., vol. 22, pp. 308-311.

Griffith, J.C. (1951) Size versus sorting in some Caribbean sediments: Jour. Geol., vol. 59, pp. 211-243.

_____ (1967) Scientific method in analysis of sediments: McGraw-Hill Book Co., New York, pp. 436-484.

Harvey, R.D. and Vitaliano, C. J. (1964) Wallrocks alteration in the Goldfield District, Nevada: Jour. Geology, vol. 72, pp. 564-579.

Jedwals, J. (1965), Characterization spectrochemique des granites; I, Granites a deux micas de guehenno et de la villeder (Morbian, France): Soc. Belge Geol., B.t. 64, f. 3, pp. 526-534.

Koschmann, A.H. and Bergendahl, M.H. (1968) Principal gold-producing districts of the United States: U.S.G.S. Prof. Paper 610.

Krumbine, W.C. and Graybill, F.A. (1965) An introduction to statistical modelaism geology: McGraw-Hill Book Co., New York, pp. 233-245.

Longwell, C.R., Pampeyan, E.H., Bowyer, B. and Roberts, R.J. (1965) Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines, Bull. 62, pp. 112-116.

Meyer, C. and Hemley, J.J. (1967) Wall rock alteration: Geochemistry of Hydrothermal Ore Deposits, edited by Barnes, H.L., Holt, Rinehart and Winston, Inc., pp. 166-235.

Morris, H.T. and Lovering, T.S. (1952) Supergene and hydrothermal dispersion of heavy metals in wall rocks near ore bodies, Tintic District, Utah: Econ. Geology, vol. 47, pp. 636-716.

Neville, A.M. and Kennedy, J.B. (1968), Basic statistical methods for engineer and scientists: Scranton, Penna., International Textbook Co., pp. 203, 221.

Ronsom, F.L. (1907), Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada: U.S.G.S. Bull. 303, pp. 67-79.

Shrivastava, J.N. and Proctor, P.D. (1962) Trace element distribution in the Searchlight, Nevada quartz monzonite stock: Econ. Geology, vol. 57, pp. 1062-1070.

Slavin, W. (1968), Atomic absorption spectroscopy: Interscience Publishers, 307 p.

Strahler, A.N. (1954), Statistical analysis in geomorphic research: Jour. Geol., vol. 26, pp. 1-25.

APPENDIX A

Tables 1 through 7

Table 1. Trace elements concentration of rock samples, Chief of the Hill Mine, Line A.

Sample Number	Distance in Feet	Elements in ppm			Elements in ppb	
		Cu	Zn	Pb	Ag	Au
992	1	86	142	124	10760	14750
993	2	44	135	103	5920	30150
994	3	14	122	48	4200	200
995	4	34	59	41	2760	93
996	5	27	100	47	2270	152
997	6	18.4	99	42	1910	25
998	7	9	78	41	1470	10
999	8	10.2	60	47	820	20
1000	9	7.5	45	37	790	30
1001	10	7.9	95	43	770	24
1002	11	5.9	71	39	1110	8
1003	12	6.8	68	38	320	5
1004	13	7.4	65	40	590	4
1005	14	6.4	80	59	330	11
1006	15	6.5	70	47	680	7
1007	16	9.7	80	46	410	14
1008	17	11.5	72	41	490	33
1009	18	6.7	76.9	47.5	495	22
1010	19	9.6	70	41.6	510	16
1011	20	10.3	72.4	41.2	600	15
1012	21	4.5	79.9	44.4	413	19
1013	22	4.0	74.7	41	375	14
1014	23	6.4	67.5	40	470	14
1015	24	4.8	75	41	307	13
1016	25	4.5	77	43	337	15
1017	34	3.7	72	39	391	11
1018	37	3.0	76.7	42	513	12
1019	40	5.7	72	40	520	10
1020	43	4.3	71	44	345	9.6

Sample Number	Distance in Feet	Elements in ppm Cu	Zn	Pb	Elements in ppb Ag	Au
1021	46	5.5	77	41	335	9.1
1022	49	5	74.4	44	305	8.7
1023	53	5.5	73.9	41	406	8.7
1024	56	6.3	75	40	410	7.6
1025	39	11.2	76.4	42	433	7.9
1026	63	9.5	78	41	440	6.9
1027	69	8.5	67.4	39	450	6.7
1028	73	7.5	71.3	39	435	6.6
1029	76.5	7.4	72.3	42	290	6.7
1030	80	7.3	79	43	290	5.6
1031	85	6.5	71.9	41	150	4.9
1032	90	5	67	39	145	5.0
1033	95	8.9	72	38	101	3.8
1034	100	3.7	76.6	40	110	3.6
1035	110	3	72	42	110	3.6
1036	120	7.9	74	43	95	3.3
1037	130	3.2	96	44	115	4.2
1038	140	5	68	39	112	2.0

Table 2. Trace elements concentration of rock samples, Chief of the Hill Mine, Line B.

Sample Number	Distance in Feet	Elements in ppm Cu	Zn	Pb	Elements in ppb Ag	Au
1051	vein	81.5	150	135	9550	9200
1052	1	7.5	77	82.5	5210	190
1053	2	7.3	63	55.4	4630	56
1054	3.5	13.8	64	39	2030	25
1055	4	15.4	63	37	733	10
1056	6	16	71	41	532	4
1057	8	12.4	74	41	535	20
1058	10	12	77	44	446	30
1059	13	19	72	44	1417	5
1060	16	15.6	72	45	995	36
1061	19	16.7	79	49	688	40
1062	22	19	65	50	590	38
1063	26	14.5	62	45	793	23
1064	30	6.4	56	40	617	10
1065a	35	6.4	68	45	852	10
1065b	40	8.4	69	41	159	10
1066a	45	13.8	68	41	234	12
1066b	50	13.5	75	51	274	9.3
1067a	60	16.4	70	49	60	9.1
1067b	70	6.5	71	51	96	8.5
1068	80	6.5	69	43	56	8.4
1069	90	7.5	72	45	55	7.2
1070	100	7.5	68	43	44	6.5
1071	110	9.5	69	40	42	6.4
1072	120	11	69	44	41	4.5
1073	130	7.5	75	38	37	3.5
1074	140	7.5	72	37	23	3.3
1075	150	9.4	74	38	48	3.2
1076	160	6.5	73	42	62	3.2

Sample Number	Distance in Feet	Elements in ppm			Elements in ppb	
		Cu	Zn	Pb	Ag	Au
1077	172	7.4	67	36	35	9.5
1078	187	6.5	66	35	45	2.9
1079	194	8.5	67	31	43	2.7
1080	200	7.5	76	31	37	2.7
1081	210	9.4	68	35	38	2.6
1082	225	10.5	70	33	45	2.5
1083	250	8	71	32	38	2.4

Table 3. Trace elements concentration of rock samples, Chief of the Hill Mine, Line C.

Sample Number	Distance in Feet	Elements in ppm Cu	Zn	Pb	Elements in ppb Ag	Au
959	vein	198	180	120	27014	11049
960	0.4	185	166	85	23251	1025
961	0.5	21	85	55	21187	1496
962	0.7	27	104	45	20802	1218
963	1.2	14	98	35	18332	32816
964	1.3	5	120	32	15160	935
965	2	6	130	58.5	14934	673
966	3	8	132	58	14671	873
967	4	18	130	68	14671	829
968	5		132	63	14460	620
969	6	27	84	35	11280	62
970a	7	19	80	35	2990	27.5
970b	7	19	82	36	2400	6.6
971	8	14	90.5	45	1811	5.6
972a	9	11	95	32.5	1316	22.3
972b	9	15	93	32	1269	21.5
973a	11	12	66	32.5	1277	10.3
973b	11	18	68	35	1358	11.5
974a	14.5	21	86.5	30	878	10.5
974b	14.5	24	75	32	978	9.5
975a	16	11	70	31.5	350	4.3
975b	16	15	74	33	450	5.7
976a	18	16	72.5	30	378	4.1
976b	18	18	74	32	390	6.5
977a	20	12	72	35	298	10
977b	20	1	75	33	320	3.9
978a	22	12	72.5	32.5	283	4.7
978b	22	14	69	31	275	5.7
979a	26	23	60	35	243	23.9
979b	26	23	68	34	260	25
980a	29	23	72.5	27	219	11.4
980b	29	14	71.5	28	280	7.3

Sample Number	Distance in Feet	Elements in ppm			Elements in ppb	
		Cu	Zn	Pb	Ag	Au
981a	32	9	72.5	38.5	150	3.6
981b	32	11	73	37	190	5.6
982a	36	15	66	325	230	4.16
982b	36	17	74	31	250	4.5
983a	40	13	69	28.5	150	4.42
983b	40	17	66	36	140	5.7
984a	44	24	71.5	38.7	193	4.14
984b	44	27	72	35	120	4.5
985a	48	15	68	31	120	24
985b	48	12	65	34	170	25
986a	53	13	69.5	37	93	9.2
986b	53	15	71	36	158	9.3
987a	57	10	71.5	35	89	7.9
987b	57	12	73	33	101	9.1
988a	62	10	75	32.5	92.5	8.2
988b	62	17	74.7	34	85	8.6
989a	65	15	71.5	36.5	69	9.5
989b	65	19	82.6	35	70	7.5
990a	70	16	72.5	31.5	54	9.5
990b	70	14	69.5	32	69	8.5
991	75	14	66	32.5	76	4.57

Table 4. Trace elements concentration of rock samples, Chief of the Hill Mine, Line D.

Sample Number	Distance in Feet	Elements in ppm Cu	Zn	Pb	Elements in ppb Ag	Au
1084a	Vein	294	158	105	37317	12.99
1084b	Vein	114	30	98	34118	6.639
1085	1	14	91	150	27287	94
1086	2	13.5	85	39	14550	7
1087	3	2	87	39	11110	9
1088	3.5	17.5	93	38	9840	23.9
1089	4	3	114	39	7874	22.8
1090	5	2	123	43	1322	13.4
1091	6	12.5	125	33	6320	4
1092	7	15	76	38	6120	5
1093	8.4	23	69	35	6190	3.1
1094	9	5	112	35	6340	7.2
1095	11	25	64	43	3670	3.5
1096	14	5	88	33	2450	6.8
1097	15	3	89	31	1270	5.9
1098	16	4	65	30	1030	6.2
1099	17	6	65	32	990	19
1100	18	3	76	35	750	6.4
1101	19	5	79	35	630	7.8
1102	21	8	43	33	590	5.2
1103	23	14	50	31	580	5.3
1104	North Side	11	26	31	7690	7.9
1105	9	10	123	33	13680	8.5
1106	6	4	50	37	17270	8
1107	4	22	145	54	21320	125
1108	3	105	158	103	38926	291

Table 5. Trace elements concentration of rock samples, Duplex Mine, Line E.

Sample Number	Distance in Feet	Elements in ppm Cu	Zn	Pb	Elements in ppb Ag	Au
1251	vein	27580	9850	16532	10861	9534
1252	vein	23386	9960	14327	9963	9343
1253	.2	4575	8075	6820	2367	1280
1255	.2b*	1050	1000	1270	1713	1123
1256	.5b*	1050	1050	1320	1113	1281
1257	.1b*	3950	1000	1650	1181	2332
1260	.5h**	5000	1010	6500	2467	1096
1261	.1**	5000	1000	3930	2769	1968
1262	.2	5700	5700	3850	1846	335
1263	.5	875	1100	3800	1867	182
1264	1.0	440	1000	1170	2467	233
1265	2.3	360	870	945	1707	13
1266	3.7	405	1000	930	923	17
1267	4.7	400	1000	396	210	23
1268	5.7	375	500	385	784	40
1269	7.1	295	525	381	315	58
1270	8.7	295	530	378	980	84
1271	10.0	200	445	385	542	97
1272	10.7	215	500	245	473	40
1273	11.7	240	530	530	593	20
1274	12.7	250	500	335	378.5	42
1275	13.7	145	535	195	378.4	67
1276	14.7	175	675	307	192.3	54.6
1277	15.7	125	725	307	278.4	50
1278	17.7	170	575	265	182.4	52.4
1279	18.7	290	359	290	299.5	62.2
1280	20.7	350	675	180	263.7	54.1
1281	22.7	245	515	170	281.5	54.3
1282	25.7	265	675	370	250.7	82
1283	27.7	50	575	240	144.1	75.7

Sample Number	Distance in Feet	Elements in ppm Cu	Zn	Pb	Elements in ppb Ag	Au
1284	30.7	110	670	350	151.3	51.4
1285	32.7	105	625	325	133.5	65.4
1286	35.0	145	500	300	±65	35.5
1287	38.7	145	670	345	122	65.7
1289	39.7	50	675	255	122.5	37.5
1290	41.7	12.5	350	265	147	65.5
1291	44.7	29.5	465	230	152.7	50.0
1293	47.7	5	390	145	123.8	28.5
1294	44.7	47.5	675	130	142	26.7
1296	54.7	42.5	465	175	131	20.9
1298	60.7	42.5	335	145	131	20.3
1299	63.7	42.5	195	155	129.5	18.7
1300	67.7	35.5	250	155	120.9	23.8
1301	70.7	57.5	450	175	128.1	19.5
1302	73.7	43.5	365	110	121	7.2
1303	76.7	60	425	±40	125.5	8.2
1304	79.7	60	340	150	121.5	11.6
1305	83	5.5	240	110	138	7.8
1306	86.7	7	165	110	137	6.3
1307	91	10	175	90	144	3.8
1308	94.7	3.5	165	80	132	4
1309	98.7	15.6	105	60	137	4.2
1310	100	12.5	106	50	32	6.3

*Bottom of the vein

**Upper part of the vein

Table 6. Trace elements concentration of rock samples, Duplex Mine, Line F.

Sample Number	Distance in Feet	Elements in ppm Cu	Zn	Pb	Elements in ppb Ag	Au
1551	vein	20500	6372	12500		
1552	vein	27250	1995.9	12080		
1553	vein	58760	4510.	2525		
1554	vein	32426	4932	4265		
1555	3-4"	5150	2582	3650		
1556	6-10"	7250	5050	6980		
1557	12"	3750	5750	7232		
1558	1	2250	3334	6462		
1559	1.7	420	897.8	1065		
1560	3	300	810.5	1050		
1561	4	325	729	932		
1562	6	225	451	620		
1563	10.4	110	607	310		
1564	11.4	32.5	420	260		
1565	13	9.5	190	250		
1566	15	9	213	170		
1567	17	18	213	135		
1568	19	28	183	65		
1569	21	30	118	80		
1570	23	20	135	79		
1571	25	17.5	82.5	65		
1572	27	10.5	70	70		
1573	29	9.5	82	60		
1574	31	9.5	110	100		
1575	33	4.5	103	90		
1576	36	9.5	56	45		
1577	39	19	62	36.5		
1578	42	15.5	66.5	36		
1579	45	13.5	96	65		
1580	48	3	45	35		

Sample Number	Distance in Feet	Elements in ppm			Elements in ppb	
		Cu	Zn	Pb	Ag	Au
1581	49	45	35	35		
1582	51	9	44	35		
1584	55	12.5	55.5	35		
1586	75	14	81	45		
1588	85	17.5	57.5	45		
1590	95	16	55	35		
1591	100	10	54	34		

Table 7. Trace elements concentration of rock samples, Duplex Mine, Line G.

Sample Number	Distance in Feet	Elements in ppm Cu	Zn	Pb	Elements in ppb Ag	Au
1200	vein	18400	1990	9300	9878	10202
1201	1	14820	1695	7836	6323	2343
1202	2	7350	1200	8350	5890	1250
1203	3	640	710	970	1132	523
1204	4	613	525	695	1250	325
1205	5	570	360	732	1780	102
1206	5.6	523	495	658	1650	153
1208	6.5	360	530	234	981	8
1209	7	270	560	314	813	13
1210	8	250	530	434	130	19
1211	9	94	520	422	145	10
1212	10	82	620	425	136	9
1213	11	247	360	445	40	3
1214	12	163	548		161	9
1215	13	140	592	365	99	2
1216	14	143	440	422	211	14
1217	15	156	352	342	50	29
1218	16	149	280	280	257	33
1219	17	158	360	451	492	34
1220	18	105	320	268	63	8
1221	19	148	380	251	208	15
1222	20	110	384	234	198	11
1223	21	122		213	481	12
1224	22	113	210	198	210	25
1225	24	40	220	194	385	36
1226	26	186	270	188	82	9
1227	28	71.2	270	269	253	18
1228	30	64.7	158	170	241	12
1229	32	33	82	101	41	2
1230	34	40	66	53	82	9

Sample Number	Distance in Feet	Elements in ppm Cu	Zn	Pb	Elements in ppb Ag	Au
1231	36	35	96	48	28	12
1232	38	38	85	37	15	8
1233	40	28	63	42	18	9
1234	42	27	76	37	73	14
1235	43	19	62	33	53	13
1236	44	21	58	40	20	9
1237	45	19.5	65	29	75	10
1238	48	15.7	70	34	83	8
1239	52	10.5	75	53	43	6
1240	56	12.3	70	38	86	9
1241	60	10.7	66	42	90	4
1242	63	9.5	45	22	70	4
1243	67	8.4	70	34	60	4
1244	71	8.5	69	33	55	5
1245	75	8.4	68	33	56	4

VITA

Zuhair Al-Shaieb was born in Damascus, Syria on September 28, 1940. He attended elementary and high schools in Damascus graduating in 1958. He enrolled at Ain-Shams University in Cairo, Egypt from 1959 to 1961. He received the Bachelor of Science degree in Chemistry and Geology in 1963 from Damascus University. He also holds a General Diploma of Education from the same University. He taught chemistry and geology at Kuwait High School from 1964 until 1966.

He enrolled as a graduate student in geology at the University of Missouri-Rolla in September, 1967. Currently, he is a Graduate Research Assistant in the Geology Department.

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